JOURNAL

OF THE

AMERICAN SOCIETY OF NAVAL ENGINEERS

VOL. XXI. MAY, 1909. No. 2.

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UNDERWATER TORPEDO BOATS.

"SUBMARINES" OR "SUBMERSIBLES."

BY LAWRENCE SPEAR, MEMBER.

The title of this paper has been selected with some care on account of the multiplicity of definitions of the terms "submarine" and "submersible." Even the casual reader of the literature on this subject must have noticed that most writers select or originate their own definitions, and arbitrarily class existing types of underwater craft in the manner best suited to sustain their particular theories or contentions. Generally speaking, there has been an amusing scramble on the part of designers to class their own products under the term "submersible" and as many as possible of the rival types under the term "submarine." The obvious motive lies in the fact that the "submarine" proper as developed in France has been discredited by trials and practical experience as compared with the French "submersible." The matter would be of no importance if the *facts* were adhered to and if the conclusions drawn

were applied only to the actual designs or types tested. Unfortunately, however, controlling facts are entirely disregarded, broad and unsound conclusions are jumped at which, on account of some resemblance, fancied or invented, are applied to designs radically different in essentials and from which radically different practical results have been obtained. Under these circumstances, the author may be pardoned for undertaking a brief historical review of the conditions which originally gave rise to the terms.

These terms are of French origin and, strictly speaking, are only applicable to French boats. Outside of France the broad term "submarine" is generally used to designate all vessels capable of navigating totally submerged. The word is also used in that sense in France, but, in addition, is frequently used in a restricted sense, to distinguish one general type of French boat from another, termed "submersible." The first underwater boats built in France were fitted only with electric power and had no heat engines for surface propulsion and recharging batteries. As these were incapable of action independent of their base, the qualities necessary for cruising on the surface, particularly at sea, were unimportant; hence, in the light condition (that is, with all ballast tanks empty) they had a very small reserve of buoyancy—only about 4 per cent. or 5 per cent. That is, in the condition of maximum freeboard they were almost awash. This was permissible because under the worst conditions at sea which they were apt to encounter the boats could be completely sealed up, as they did not require any air supply for propulsion. The first of these vessels were originally designed to submerge by inclining the axes under the action of stern rudders only. The proportions of the vessels, however, were eminently unsuitable for this method of submergence, and it was found impossible to control them by this method with any certainty. Additional rudders were therefore fitted both forward and aft, equally distant from the center of gravity, so that a vertical thrust could be produced in addition to the turning moment due to the stern rudders. Owing to the vertical thrust of the side rudders the vessel could

submerge and rise with very slight inclinations of the axis. These means were found better suited to vessels of the form and proportion of those in question, and have been adhered to ever since. In 1899 the *Narvel*, the forerunner of a new type for France, was launched. She was termed a "submersible" because, in addition to her underwater work, she was especially designed to cruise on the surface like an ordinary vessel, steam engines being fitted for that purpose. The use of steam engines, of course, involved comparatively large deck openings for the purpose of supplying air and exhausting the products of combustion. To meet these conditions safely and at the same time render the vessel sufficiently habitable and comfortable in a seaway the reserve buoyancy in the light condition, *i.e.*, all ballast tanks empty, was very materially increased as compared with the earlier boats, or "submarines" proper. The means for submergence and control when submerged, *i.e.*, multiple rudders, were identical with the final form of the "submarine." In accomplishing this the hull construction and external shape of the vessel were materially modified, the circular-section hull of the "sous-marine" proper being enclosed in a light hull, more or less ship shape, the intervening space constituting ballast tanks.

A fair conclusion from this is that the term "submersible" as originally employed in France had no direct reference to the shape of the hull or to the amount of reserve buoyancy or the means adopted for submerged control, but was employed to convey the idea of a vessel designed to navigate on the surface propelled by heat engines in open communication with the atmosphere, but capable at will of submersion. The differences in form and buoyancy flowed from the supposed requirements for surface navigation. In the course of events, however, these secondary considerations have been advanced to the dignity of primary and controlling elements, so that the following distinctions and definitions have been advocated or used from time to time:

(*a*) "Submarine." A vessel designed primarily for submerged operation, equipped only with electric power and hav-

ing only a small percentage of reserve buoyancy, for surface navigation, together with a very limited radius of action.

" Submersible." A vessel designed not only for submerged operation, but also for navigation on the surface, with a considerable radius of action, equipped not only with electric power for submerged propulsion, but also with a heat engine for surface propulsion, and having a materially greater reserve of surface buoyancy than the " submarine."

(*b*) " Submarine." Any boat equipped for navigation both on the surface and submerged, having a small reserve of buoyancy, say, not exceeding 10 per cent. of submerged displacement.

" Submersible." The same, with a larger percentage of buoyancy.

(*c*) " Submarine." A boat equipped for both surface and submerged navigation, characterized by the external form of hull, being a spindle of revolution, or modifications thereof.

" Submersible." The same with an external form of hull, in general representing the ordinary " ship form," and more particularly resembling the surface torpedo boat.

(*d*) " Submarine." Any underwater boat effecting its plunge by inclination of its axis, controlled by horizontal stern rudders only.

" Submersible." Any underwater boat effecting its plunge by the use of multiple rudders or by combination of rudder and inclining planes, sometimes termed " hydroplanes."

Evidently there is now no definite and accepted scientific distinction between the terms, and no cogent reason for their separate employment, especially as the true French "sous-marine" is a discarded and obsolete type. The word "submarine" is often and properly used in a broader sense to cover all types, but on account of the above confusion the author here prefers the term " underwater."

A study of the best known types of such craft reveals a certain fairly definite line of cleavage, perhaps partly the result of different opinions as to the relative value of certain conflicting qualities, but also no doubt due in part to commer-

cial reasons. As in the later types commercially developed, it was not only necessary to avoid the patents on pioneer types, but desirable, for business reasons, to present *something different* upon which to base claims for new or improved qualities. Broadly speaking, they may be divided into two classes, within the boundaries of which there is a general similarity. An attempt at such a division will be made below, but before doing so some considerations of certain general principles is desirable.

CONFLICTING REQUIREMENTS.

The qualities best suited for surface navigation unfortunately conflict with the submarine operations for which the boats are primarily constructed. This conflict is inevitable, as it has been conclusively demonstrated that the form and more especially the proportions best suited for a high surface speed are not favorable to a high submerged speed, or to adequate and easy control of such speed. Theoretical considerations, model trials and actual results achieved with full-sized boats prove conclusively that the best submerged qualities are obtained with a form the base of which is a spindle of revolution of certain fairly definite proportions. It is a fact, however, that these proportions, rather than the form, place strict limits on the surface speed. In one practical case, for instance, the submerged speed for a given power was greater than the surface speed, notwithstanding the increase in wetted surface submerged. It is also true that the *pure* spindle of revolution with a small reserve of buoyancy is not too well adapted to a high surface speed by reason of tendencies to undesirable changes of trim. These are the result of forces due to wave formations and stream-line action acting against a resistance to change of trim, materially less than that of the ordinary "ship form" of the same displacement. This lessened resistance is, of course, due to the smaller water-line area, with the consequent reduction in the longitudinal moment of inertia of that area. Obviously such conditions improve with increase in buoyancy and grow worse with its decrease, not only with

respect to the resistance offered by the longitudinal stability, but also with respect to the forces acting to change trim.

Fig. 1 indicates such a pure spindle form with water lines corresponding to 5 and 15 per cent. buoyancy. A glance at this will show why the resistance to change of trim increases so rapidly with increase in buoyancy. In this case the resist-

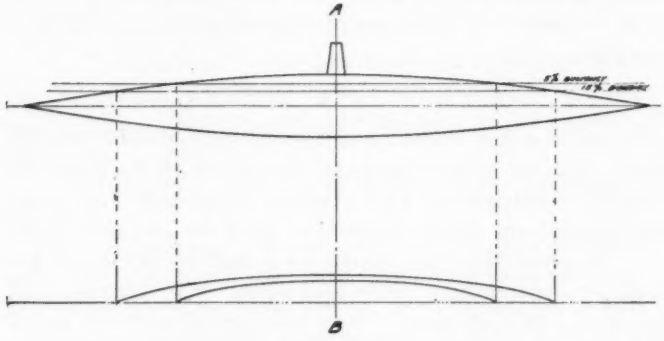


Fig. 1.

ance to change of trim for the 15 per cent. line is almost four times that for the 5 per cent. line. In addition, the forces tending to change of trim are materially less at the 15 per cent. line, so that the practical difference in behavior is even greater than that represented by the factor four.

It is important to note that the above criticism is applied to and true of the *pure* spindle form only, and is without force or point when applied to certain modified spindle forms mentioned below.

To improve the surface qualities the simplest remedy is to modify the proportions and the form of entrance and run so as to lessen resistance at high speed and decrease the forces acting to change trim, and at the same time increase the resistance to change of trim by increasing the area of water plane. The latter is most effectively done by lengthening the water line, thus adding the area at the most effective place—the ends. Evolution along these lines has taken place, but what concerns

us now is that this solution of the difficulties of surface navigation adds material difficulties to the submerged navigation. The practical effect of this course is to produce a form more or less ship shape and generally with large flat-deck areas, combined, where high surface speed is sought, with fine lines and great proportion of length to beam and depth. These general changes have a very detrimental effect upon the submerged qualities, decreasing the speed, stability, strength and maneuvering powers, while increasing the difficulty of control and the complexity of the controlling mechanism. As will appear later, these disadvantages should really be considered prohibitive, and with them in mind another line of development has been followed whereby it was sought, and successfully, to secure acceptable and safe surface qualities without the grave sacrifices outlined above.

CLASSIFICATION OF TYPES.

It is with respect to the lines of development sketched above that the best known types may be classified, as follows:

First Group: (*a*) The Holland type as developed and modified by the staff of the Electric Boat Company under the direction of the author, and built for the United States, Japan, Russia, Austria and Holland.

(*b*) The Holland type as developed by Messrs. Vickers Sons & Maxim and the British Admiralty for the British Navy.

Second Group: (*a*) The French type ("submersible") developed from the *Narval,* designed by M. Labeuf.

(*b*) The Krupp type, developed from the designs of M. D'Equivilley.

(*c*) The Laurenti type, built by the Fiat San Giorgio, Spezia, Italy.

(*d*) The Lake type, built by the Lake Torpedo Boat Company from the designs of Mr. Simon Lake.

It will be noted that a distinction is drawn between the British development of the Holland type, with which the author

has no connection, and that which has taken place elsewhere and for which he is directly responsible. The distinction is necessary, as many arguments have been based on the false assumption that the two types are essentially identical. Such is not the case, and conclusions, criticisms or theories based on the supposed performance of the one do not necessarily apply to the other. In passing, it is proper to remark that publications purporting to give detailed information as to the design and performance of British boats should be regarded with suspicion. The whole subject is behind the veil of official secrecy, and no person outside the British Admiralty is in a position to know all the facts. This applies not only to the design and normal performance of the vessels, but also to the actual facts with respect to the few deplorable and fatal accidents which have occurred in the past, concerning which much absurd pseudo-scientific nonsense has been published.

The Laubeuf, Krupp, Laurenti and Lake types naturally fall together into one group, since the final result of the designs is to produce an external form nearly ship shape, the water-line area being filled out as described above to secure as much longitudinal stiffness as possible for surface navigation. The percentage of buoyancy in these types is not uniform, but on the average will range from 20 per cent. to 30 per cent. of the total displacement. With the exception of the Laurenti type, all of them employ the circular section for the pressure-resisting portion of the hull. Starting with this hull, the Lake type is built up to a ship shape by adding a straight-sided, watertight superstructure of a width equal everywhere to the maximum beam of the hull proper. The superstructure is carried to the extreme bow and stern, and is, of course, pumped full of water as a necessary preparation for submergence. The Krupp construction is for the greater part of the boat's length almost identical with the Lake. The superstructure sides incline outboard, making the superstructure beam slightly greater than that of the hull proper, while the latter is stopped before it reaches the ends of the vessel, which, as well as the

superstructure, are filled for submergence. In the Labeuf type the circular hull is completely enclosed in a surrounding hull similar to the ordinary torpedo boat. The space between the hulls is filled for submergence. The above described spaces constitute the greater part of the surface buoyancy of these vessels: that is, they contain the greater part of the water ballast carried during submergence. As has been frequently pointed out, all these arrangements are gravely defective in that the contained ballast cannot be pumped out at great depth, since the outer skin is not strong enough to resist the exterior pressure. In the Laurenti construction no use is made of the circular section, dependence being placed upon web frames and special bracing, by which the exterior portions, including the superstructure, are utilized to help support the pressure-resisting hull. It is certain that, with equal weights, such a section cannot support as much pressure as a circular one, and, while the proportions and lines obtainable with this system are favorable to surface speed, they are lamentably inferior for submerged qualities.

In the British modified Hollands the pure spindle form for the hull proper has been adhered to, the external form being modified only by a superstructure which in the latest vessels commissioned stops considerably short of the bow and stern. (See Fig. 16.) The proportions, however, have been altered to favor surface speed. The buoyancy, while materially greater than the original French "submarine," is understood to have been generally less than the original Hollands, but in the latest construction has been increased. Exact figures are not available, but it is generally believed that the earlier boats of the A and B class have about 10 per cent. and the later vessels somewhat more. Undoubtedly these vessels are nearer to the original "submarine" than any others outside of France, and, in view of the large numbers in service and the extensive practical experience with them under severe service conditions, it is safe to assume that the greatest naval power in the world has found their surface qualities at least acceptable. Otherwise large numbers would not at this writing be under con-

struction. In that connection, it is interesting to note that this was the principal point tested in the North Sea naval maneuvers last summer. The results are shown by the following letter of commendation from the Lords of the Admiralty to the Commander in Chief:

"ADMIRALTY, *6th August, 1908.*

"SIR:

"I am commanded by My Lords Commissioners of the Admiralty to inform you that you are to acquaint the Inspecting Captain of Submarines that Their Lordships note with great satisfaction the sustained efficient service of the Submarines during the recent exercises. They note that on occasions the Submarines were self-contained, and that for two periods of five and seven days, respectively, the crews did not leave their boats. The run of over 400 miles in under 40 hours, and the further run on the next day of 200 miles, taken in conjunction with the fact that no defects were developed during these runs, are conclusive evidence of the efficiency of the Submarines and of their Officers and Crews and of the excellence of the organization of the Submarine Service.

"Their Lordships' thanks and appreciation of the work performed are to be conveyed to the Inspecting Captain of Submarines for the information of all under his command."

The very large number of boats involved, viz: thirty-five, adds additional significance to the performance, and as the "owners" regard the evidehce as conclusive, it should satisfy any unprejudiced mind.

In the author's designs the departures from the pure spindle form have been more extensive. The superstructures are carried to the extreme bow and stern. Moreover, the hull proper is not a spindle of revolution, except at the midship portion. The entrance and run are suitably modified to secure the desired qualities on the surface and awash with the least possible detriment to the submerged qualities. Exhaustive trials have demonstrated that the modifications are effective, and in the face of those demonstrations it is idle to assert either that the

surface qualities are not acceptable or that the submerged qualities are not superior to those demonstrated by any other type whatsoever. The buoyancy percentage has ranged from 14 per cent. to 20 per cent.

In altering proportions to favor surface speed the author has deemed it wise to "make haste slowly." Development in that direction has taken place, and further development is in hand, concurrent with a very material increase in radius of action. The controlling element of this development is the firm conviction that it should cease the moment it seriously interferes with submerged speed, radius, etc., as the latter are of much greater military importance.

COMPARATIVE RESULTS WITH THE TWO GENERAL TYPES.

It has been asserted above that the ship-shape type unduly sacrifices submerged qualities, and it is now proposed to demonstrate this fact by a comparison of actual results achieved, which comparison will also show that the sacrifice has been in vain so far as any compensating surface speed is concerned. This proposition is set forth only as a *general* one, hence *average* results must be compared. If individual cases are employed the comparison is really between the skill of the designers, and not between the general types. Even so, the facts show that in all cases there is a sacrifice of the submerged speed, and in the single instance where surface speed is really gained the corresponding sacrifice of submerged qualities is very serious.

Not the least wonderful thing about underwater boats is the shrinkage which takes place between the speeds claimed by some of the designers and promoters and those actually achieved on properly conducted trials. Therefore, any figures except those secured as the result of official trials, honestly conducted, are worse than useless. So-called "guaranteed speeds," unless they correspond closely with actual results previously obtained with the type, must be viewed with suspicion. At best they represent only rosy hopes; at the worst,

nothing, since it is usual to make provision for the acceptance of vessels at speeds materially below these "guaranteed speeds." Owing to the prevailing rule of secrecy it is impossible to obtain authentic official data for all types with regard to all of the features necessary to a proper comparison, and in some cases it is impossible to obtain any official information whatsoever. These facts unfortunately limit the demonstration given below (for all except the Lake type) to a few of the most important qualities. The competitive trials held between the *Octopus* and the *Lake* at Newport in May, 1907, are a source of reliable official data, which it is now proper to use, since the essential information has already been published in scattered form, and there can be no valid objection to its reproduction here. A complete and accurate comparison of military value would require that all vessels have the same displacement, the same strength to resist submergence pressures, and be substantially equal in seaworthiness, habitability, armament and durability, leaving the following qualities to be compared:

Submerged speed,
Submerged endurance,
Surface speed,
Surface endurance,
Time required to submerge,
Maneuvering powers,
Simplicity and safety.

Factors applied to these to represent their relative value would give a final result in numerical form, comparison of endurance of course being made at the same speed. It is unfortunate that the data are not available for such a comparison, as it would undoubtedly bring out some very sharp distinctions not now clearly realized.

Tables I to IV give such information as is available for the types under discussion. In order to avoid the influence of displacement so far as practicable, the type vessels selected all have displacements between 204 and 273 tons.

The figures as to safe depth of submersion are the results of actual tests only in the case of the *Lake* and *Octopus*. The

speed figures for the Laurenti boat are *minimum* guarantees for a boat just completed, and do not purport to be trial figures. All other speed figures are the result of official tests. In the column headed "Relative" the lowest figures are given a value of 100, so as to express the comparative results in percentages, and the vessels are numbered in the order of merit.

Table I.—SHIP FORMS—SPEED.

Name.	Disp. submerged.	Maximum surface speed.		Name.	Disp. submerged	Maximum submerged speed.	
	Tons.	Knots	Relative.		Tons.	Knots.	Relative.
Laurenti..	230.0	14.0	184	Krupp....	240.0	9.0	159
Krupp.....	240.0	11.0	145	*Aigrette.*	262.0	6.3	111
French *Aigrette*	262.0	8.7	113	Laurenti.	230.0	6.0	106
Lake.....	230 0	7.6	100	Lake.....	230.0	5.65†	100
Average...	240 5	10.3	...	...	240.5	6.74	...

†Uncontrollable at this speed.

Table II.—MODIFIED SPINDLE FORMS—SPEED.

Name.	Disp. submerged.	Maximum surface speed.		Name.	Disp. submerged.	Maximum submerged speed.	
	Tons.	Knots.	Relative.		Tons.	Knots.	Relative.
Octopus...	273.0	11	145	*Octopus*...	273.0	10.0	177
English *A-5*...	204.0	11	145	English *A* class.	204.0	7.5	132
Average...	238.5	11	...	...	238.5	8.75	...

Table III.—SUMMARY OF AVERAGES—SPEEDS.

Type.	Average displacement submerged.	Average surface speed.		Average submerged speed.	
	Tons.	Knots.	Relative.	Knots.	Relative.
Modified spindle.	238.5	11.0	107	8.75	130
Ship forms.....	240.5	10.3	100	6.74	100

This table shows that on the same tonnage the modified spindle type not only gives 30 per cent. greater submerged speed, but also 7 per cent. greater surface speed. Lack of com-

plete data prevents extending the table of averages to cover radii of action. Trial data, Table IV, are, however, available for the *Lake* and *Octopus* and *minimum* guarantee data for the Laurenti.

Table IV.

Name.	Corresponding surface speed.	Surface radius.		Corresponding subm'rgd speed.	Submerged radius.		Average relative.
		Knots.	Relative.		Knots.	Relative.	
Octopus...	8.0	1,050	266	6.37	60.0	500	414
Laurenti..	...	...	...	6.00	12.0	100	...
Lake.....	7.25	395	100	5.65	17.0	142	...
Average...	...	...	...	...	14.5	...	100

It will be noted that the surface radius of the *Octopus* is (even at a higher speed) 166 per cent. greater than the *Lake*. The difference in submerged endurance is even more startling, being 400 per cent. greater than the Laurenti and 314 per cent. greater than the average of the *Lake* and Laurenti.

When we consider, in addition to the above facts, that the submerged stability of the *Octopus* is higher, the rapidity of maneuvers in the vertical plane greater, and the safe depth of immersion 200 feet against 125 to 140 feet for the other types, the case is conclusively demonstrated.

The photographs, Figs. 9 to 25, give a fair general idea of the characteristic appearance of the various types and will repay study with respect to the actual forms of the vessels and to the real conditions as to freeboard and buoyancy. Particular attention is invited to the contrast between the real French "submarine" *Lutin*, 185 tons, and the Electric Boat Company's *7-P*, 122 tons, and *Octopus*, 273 tons. Even casual inspection by a seafaring man will show the absurdity of saddling the last-mentioned types with the seagoing and surface defects of the former. Moreover, a comparison of the *Octopus*, 273 tons, with the *Lake*, 235 tons, the Krupp, 240 tons, and the Lebuef, 265 tons, leaves no room for wonder that her seagoing and surface qualities are at least equal to theirs.

THE VALUE OF SUBMERGED SPEED.

Reference has already been made to the paramount importance of submerged qualities. The writer's convictions on that subject are grounded on the simple fact that the sole function of the boat is performed under water. It is built to fight there, and its chances of success are very largely dependent upon its submerged speed and endurance. These are its most important tactical qualities. Its surface speed is of but little tactical importance, and never will become important unless it can be made greater than that of the battleship, thus enabling a group of boats to chase and head off their prey. The possibility of developing such a speed may be dismissed without consideration, as not now being a reasonable subject for sane discussion. As this view of the matter is not universally held, some elaboration of the subject is in order.

Starting out with the following propositions:

First. That a battleship under way has no known means of defense against a submarine attack except in her speed.

Second. That the torpedo is a weapon which is capable of disabling or destroying a battleship.

Then, if boats could be built with submerged speeds greater than the highest speed of the battleship, and a sufficient radius of action, it follows that a battleship would be disabled or destroyed whenever sighted.

Since, at the present time, it is impossible to secure such high submerged speeds, the natural conclusion would be to make the submerged speed and radius as great as practicable so as to approach as closely as possible the speed of the battleship.

As a basis for this discussion, the following data will be used:

The Torpedo.—Type, W. 5.2 m. by 45 cm., Mark V. Speed for a range of 1,000 yards, 36 knots. Mean error due to incorrect estimate of speed of enemy, etc., 150 feet at 1,000 yards. Effective torpedo range, 1,000 yards. That these assumptions are conservative can be shown by a consideration

of the test performances of this weapon and by the results of service torpedo practices which have taken place every autumn during the past few years.

The Underwater Boat, a design in which the surface speed is 14 knots, the submerged speed 11 knots for one hour. The distance at which the boat may see a battleship through the periscope is assumed to be 5 miles.

The Battleship will be assumed, at the time of being sighted by the boat, to be steaming at any speed from 8 to 20 knots, depending on circumstances.

With the above conditions, the tactics of the boat will naturally be divided into two periods. The first period is that during which the boat sees the battleship while itself remaining invisible to the latter. This period will begin when the battleship is about 5 miles distant, and will cease when the distance is decreased to 1 mile or less, when the battleship may possibly pick up the periscope. During this interval the boat will remain much of the time totally submerged, taking observations through the periscope at intervals. The speed employed during this interval may be anywhere from the maximum to the lowest limit, depending on conditions. As a rule, a low speed would be used as much as possible for the purpose of saving the battery charge for the attack. The second period begins as soon as the battleship discovers the presence of the boat, and ends either with the escape or destruction of the larger vessel. During this period the battleship will use all speed obtainable for the purpose of escape, while the boat will naturally use all its speed for the purpose of firing its torpedoes at the closest possible range.

In the diagram, Fig. 2, let the battleship be steaming at x knots along any course which brings it within 5 miles of the submarine. Let the position of the submarine be B, and that of the battleship A. The most favorable course for the battleship would be that tangent to circle of visibility of 5 miles radius, drawn around the submarine. This would be E or W in the diagram. The worst course for the battleship to be steering would be S. in the above case, as it would then

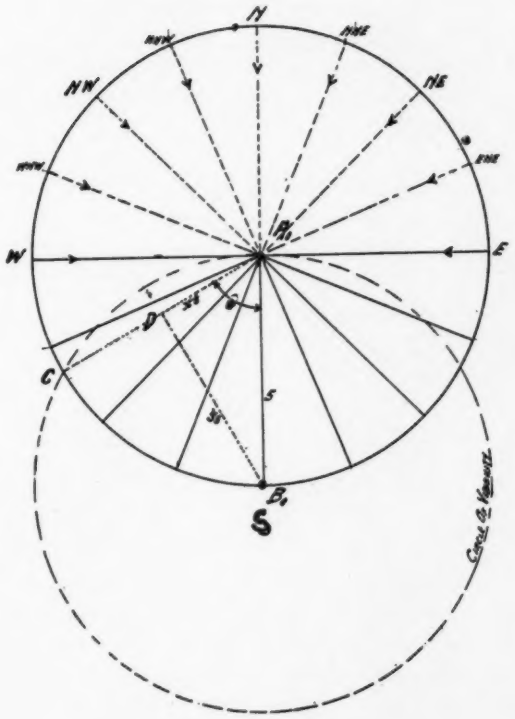


Fig. 2.

be heading directly toward the submarine. As soon as the submarine is able to estimate the speed and course of the battleship which has entered its range of vision, it would proceed by the shortest route for the purpose of coming within torpedo range. Let the speed adopted by the submarine be y knots. Let θ be the angle made by the course of the battleship with the line of bearing A_1 and B_1. Let t be the interval of time required to intercept.

Then:

$$\tan \theta = \frac{yt}{xt} = \frac{y}{x}.$$

As the battleship may be steering any course within an arc of 180 degrees, and as the danger angle θ is the same on both sides of the line of bearing A_1, B_1, the probability p of the course of the battleship lying within the danger arc 2 θ, is $\frac{2\theta}{180} = \frac{\theta}{90}$.

The following table gives the numerical values of θ and p, corresponding to different speeds used by the battleship and the submarine:

x = speed of battleship in knots.	Submarine speed when $y = 5$ knots.		Submarine speed when $y = 8$ knots.		Submarine speed when $y = 11$ knots.	
	θ	p	θ	p	θ	p
	deg. *min.*		*deg.* *min.*		*deg.* *min.*	
8	31 40	0.350	45 00	0.5	54 00	0.600
10	26 30	0.294	38 40	0.427	47 45	0.530
12	22 30	0.250	36 50	0.405	42 25	0.470
14	19 30	0.217	29 40	0.330	38 10	0.424
16	17 15	0.194	26 30	0.294	34 20	0.380
18	15 25	0.171	23 20	0.258	31 25	0.348
20	14 00	0.15	21 45	0.241	28 45	0.420

The actual distance run by the submarine is not necessarily great during this first period. Treating the problem rigidly as one of trigonometry, the distance is 5 sin θ. Thus for the maximum value at θ (54 degrees) in the table this distance is 4.0 miles, and for the minimum (14 degrees) it is only 1.2 miles.

The importance of having as great submerged speed as possible is strikingly illustrated in the above table, where the probabilities of intercepting with the 11-knot boat are about double those with the 5-knot boat.

Second Period.—Closing from 2,000 yards to 1,000 yards, assuming the battleship to be aware of the presence of the submarine and making every effort to escape.

During this period everything depends upon the relative speeds of the two vessels.

In the diagram, Fig. 3, let A_1 be the position of the battleship at the assumed time of sighting the periscope of the sub-

marine at B_1, about one mile distant. It is apparent that the only thing for the battleship to do is to turn and run in a direction away from the submarine. If the speed of the battleship be appreciably less than that of the submarine she is doomed.

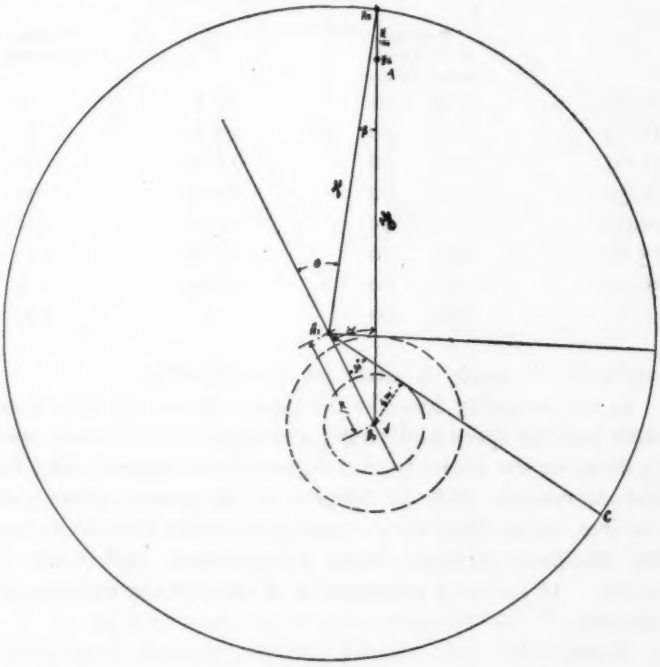


Fig. 3.

But even with an excess of speed the battleship will be forced to steam within a certain zone, relative to the line of bearing. This may be called her zone of safety, and depends upon the relative speeds of the two vessels.

Let x = speed of battleship in knots.

Let y = speed of submarine in knots

= range of submarine, provided she can run one hour at y knots.

Then from the diagram

$$\theta = \alpha + \beta, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$\sin \beta = \frac{\sin \alpha}{x}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

$$x^2 = \sin^2 \alpha + [(y + \tfrac{1}{2}) - \cos \alpha]^2, \quad . \quad . \quad . \quad (3)$$

x	θ when $y = 5$ knots.		x	θ when $y = 11$ knots.
	degrees.	*minutes.*		
10.50	127	00	10.5	0
10.75	127	30	10.75	44
11.00	128	00	11.00	64
11.50	129	00	11.50	92
12.00	129	45	12.00	104
15.00	133	30	15.00	120
30.00	139	00	30.00	131
...	150	00	...	150

where θ is the angle of safety for the battleship.

In the preceding formulæ the limitations of the submarine were both its speed and range, and these formulæ were used in deducing the angles from 0 degrees to 90 degrees. But for certain reasons, such as dangers of navigation, other submarines, mine fields, etc., a battleship might elect to run at the maximum possible angle, relying upon high speed to escape. In such case the solution of the problem would be as follows:

In Fig. 4 let

t = fraction of hour elapsed between sighting of submarine by battleship and time of submarine firing its torpedoes.

Then:

$$(x\,t)^2 + (y\,t + \tfrac{1}{2})^2 = 1$$

$$\tan \theta = \frac{y\,t + \frac{1}{2}}{x\,t}.$$

It is this solution which has been used for the higher speeds of the battleship. In these cases the distance to be run by the submarine is very small.

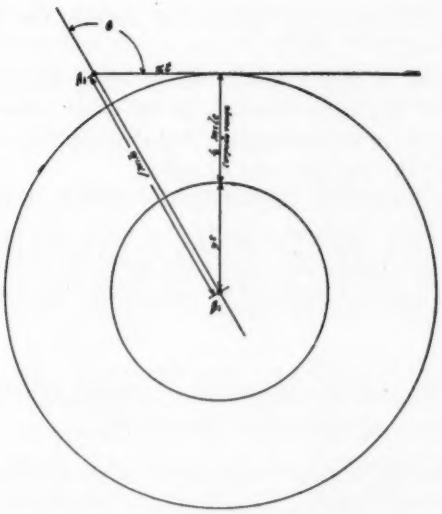


Fig. 4.

By the above table the desirability of a high submerged speed is again illustrated.

Under the above conditions the following conclusions hold true for a submarine of 11 knots submerged speed.

1. When the speed of the battleship is 10.5 knots or less escape from the submarine is impossible.

2. When the speeds of the two vessels are about equal the battleship must keep within a zone of about 60 degrees on either side of the line of bearing.

3. When the speed of the battleship is very high it may escape within a zone of about 125 degrees.

In the foregoing discussion the object has been to illustrate as definitely as possible the significance of speed in a submarine torpedo craft operating in the open sea against a battleship. No account has been taken of weather conditions, the possibility of the two vessels meeting at sea, the time taken by the battleship to turn after she sights the periscope (assuming that she does sight it), nor any of the other details which go to

make a practical case and which will operate for or against the submarine.

The general principle which makes itself manifest is that the safety of the battleship lies in its speed, directed on a course away from the submarine, and that the higher the submarine speed the less the zone of safety.

The same reasoning applied to the tactics of submarines acting in groups leads to exactly the same conclusions, and shows that the higher the submarine speed the fewer number of boats in a group required to reduce the battleship safety zone to zero.

DISCUSSION OF GENERAL FEATURES OF DESIGN, SPEEDS, ENDURANCE AND DISPLACEMENT.

In the design of any underwater boat the demands of strength, safety, stability, seaworthiness, habitability, maneuvering powers, orientation, armament, accessibility, durability and simplicity must be attained in reasonable and acceptable measure by the main features of the design, after which there is some freedom in dividing the remaining balance of space and weight between the conflicting military qualities to be sought, viz: surface speed and endurance, and submerged speed and endurance. As will be shown below, the military value of any given design is intimately related to the relative results obtained in these two respects, and, as a gain in one inevitably involves a loss in the other, this division should be most carefully made. The speeds (particularly the surface speed) achieved with any given type will depend largely upon the displacement, and, as the cost is practically proportionate to displacement, the latter should be held to the smallest limit compatible with the service required, in order that the number of units may be increased for a given expenditure, or the expenditure minimized for a given number of units.

The United States, on account of the extent and character of its coast lines, its possession of island dependencies and its responsibilities in connection with the Panama Canal, presents

conditions calling for a type of boat with a good radius of action on the surface and a surface speed sufficiently high to enable it to cruise at the economical speed of a battle fleet, say, about 11 knots. The maximum speed on trial should therefore be somewhat higher, from 13 to 14 knots.

Proper Relation Between Surface and Submerged Speeds.

Aside from this general view of the problem it is possible to arrive at a precise conclusion as to what the surface and submerged speeds of a boat should be so as to make its military value a maximum.

In any design a certain proportion of the total displacement is necessarily distributed among features not connected directly with speed. When all of these have been provided for the remaining weight is available for the installation of motive power. As an extreme case, all this weight could be used for internal-combustion engines and fuel, thus giving a high surface speed and no submerged speed. A boat of this type would have very little military value. It could be rather quickly transferred from one place to another, but after arrival at its destination it would, when submerged, be a stationary weapon, like a mine, with a radius of effect equal only to the range of its torpedoes. Boats approaching this extreme, that is, with submerged qualities largely sacrificed to surface qualities, are only justifiable where special conditions are to be met. Assuming a limited number of boats whose rôle is practically confined to the closing of a considerable number of narrow passages, it is plain that, with adequate information service, such boats would be grouped at convenient bases ready to close any one of a number of passages within their radius of action. Here a high surface speed is of paramount importance, and the submerged speed and endurance may properly be sacrificed to obtain it, as in narrow passages high submerged speed is not a tactical necessity. These considerations have led to the development of such a type for certain European countries where such conditions obtain.

The other extreme would be to utilize all the weight available in the form of batteries and motors for submerged speed only. Such a vessel would be valuable for local use, such as harbor defense, but would not be a seagoing craft. Such a type has been built in France, but its military value as an offensive weapon has been found to be small in comparison with that of a boat having a considerable surface speed and radius combined with a good submerged speed and radius. Evidently there must be a relation of surface to submerged speed which will make the general military value of the vessel a maximum under the conditions existing for the United States.

As regards the total radius of action for the surface condition, this is taken into account in the calculations which follow by including the weight of fuel carried in the weight of installation of surface motive power, and insures an ample cruising radius, as discussed above. As regards submerged radius of action, this is taken into account in the calculations which follow by limiting the time of running submerged to one hour at maximum speed, the weight of battery required for this being included. While it is thus seen that both submerged and surface endurance are taken into consideration, there is a distinction between the tactical values of the two radii. The submerged radius of action is of great tactical importance. The surface radius of action is of strategic importance, but beyond a certain amount, depending on coast lines, numbers of boats, etc., has no tactical value. In other words, if in time of war a boat is so placed that she will not be required at a distance greater than, say, 1,500 miles from her base, then any surface radius she may have in excess of this does not add to her tactical value. But everything she can gain in submerged speed and radius adds greatly to her tactical value.

In order to arrive at a mathematical expression for the tactical value in terms of surface and submerged speeds the following method may be used:

Let the boat be initially at O, Fig. 5. Let its speed on the surface be measured in the direction OX. Let its submerged

speed be measured in the direction OY. The measure of the military value of the boat may now be taken as the area it can cover in a given interval of time. Let this interval of time be one hour for surface running and another hour for submerged running. Then if the surface speed be x knots in the first hour the boat may arrive at any point in the line OX up to F, which is its limit. Now let the boat submerge and run perpendicular to its surface course. Assuming that a battleship may see a boat on the surface five miles distant, the boat must be able to

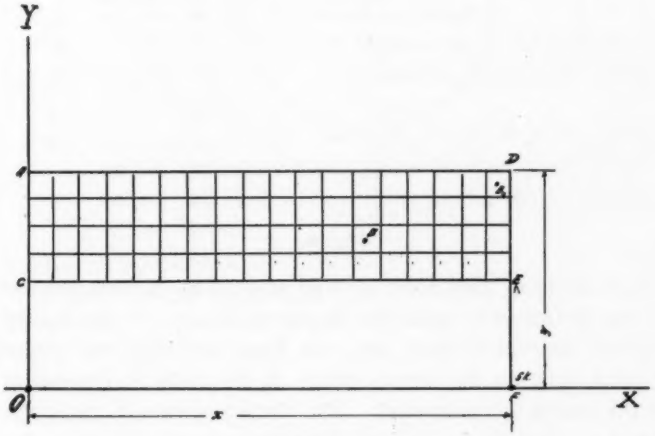


Fig. 5.

run at least five miles submerged before it begins to be effective. This distance is rather arbitrarily chosen, but, as will be shown later, it has very little effect on the ultimate results. Having chosen this distance, the rectangle $OCEF$ is an area which the boat may cover, but which is left blank, and is given no value. Now, if the submerged speed of the boat exceed five knots, she will cover an area $ACED$. If an enemy's ship be anywhere in this area it can be reached by the submarine unobserved. That combination which will make this area a maximum will represent the best type of boat for general military purposes.

Another method of establishing a standard for the measure-

ment of the military value of a boat in terms of its surface and submerged speeds is as follows:

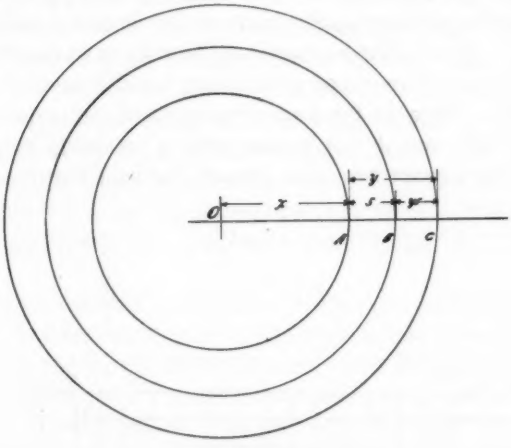


Fig. 6.

Let the boat start from any point *O*, Fig. 6, and proceed on the surface at a speed of x knots per hour. At the end of a given interval of time, say, one hour, the boat will arrive at some point on the circumference of the circle *A*, depending on the course it has steered. The circumference of this circle is $2\pi x$. Let the boat now submerge and run y knots in one hour. The total area which will include any point the boat can reach submerged will be expressed very closely by πxy. If the boat be required to run five miles submerged, so as not to be seen by the enemy, the effective area which it can cover will be expressed by $2\pi (x + 5)(y - 5)$. Call this area Z.

Then, by the first method,

$$Z = x(y - 5).$$

By the second method,

$$Z = 2\pi (x + 5)(y - 5).$$

If a surface speed be arbitrarily chosen in the design, then the submerged speed for one hour will be fixed by the remain-

ing weight available. Evidently there is a relation of x to y which will, for any one design of boat, make Z a maximum. The two methods above given practically amount to the same thing, and in actual cases give the same relative results.

If either of these standards of measurement be accepted, then it is possible, without making any assumptions, to arrive at the best relations between surface and submerged speeds for any one type of boat. To accomplish this:

Let x = surface speed in knots per hour.
Let y = submerged speed in knots per hour.
Let a = weight of one H.P. installation for surface speed.
Let b = weight of one H.P. installation for submerged speed.
Let D = total weight of all motive power.
Let C_1 = a constant, so that H.P. $= C_1 x^4$, for H.P. required on the surface at that point in the speed curve where the H.P. varies about as the fourth power of the speed.
Let C_2 = a constant, so that H.P. $= C_2 y^3$.
Then total weight surface motors, etc., $= a C_1 x^4$.
Then total weight submerged motors, batteries, etc., $= b C_2 y^3$.
$D = a C_1 x^4 + b C_2 y^3$.

$$y = \left(\frac{D - a C_1 x^4}{b C_2}\right)^{\frac{1}{3}} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

Z = area covered $= x (y - 5)$

$$= x \left[\left(\frac{D - a C_1 x^4}{b C_2}\right)^{\frac{1}{3}} - 5\right] . . \quad (2)$$

Instead of differentiating, equating to O and solving for that value of x which will make Z a maximum, values of x may be assumed, and the corresponding values of y determined from (1). The product $x (y - 5) = Z$ may then be determined. Plotting these values of Z and x, it will be seen that in every case Z has a decided maximum value for a certain value of x.

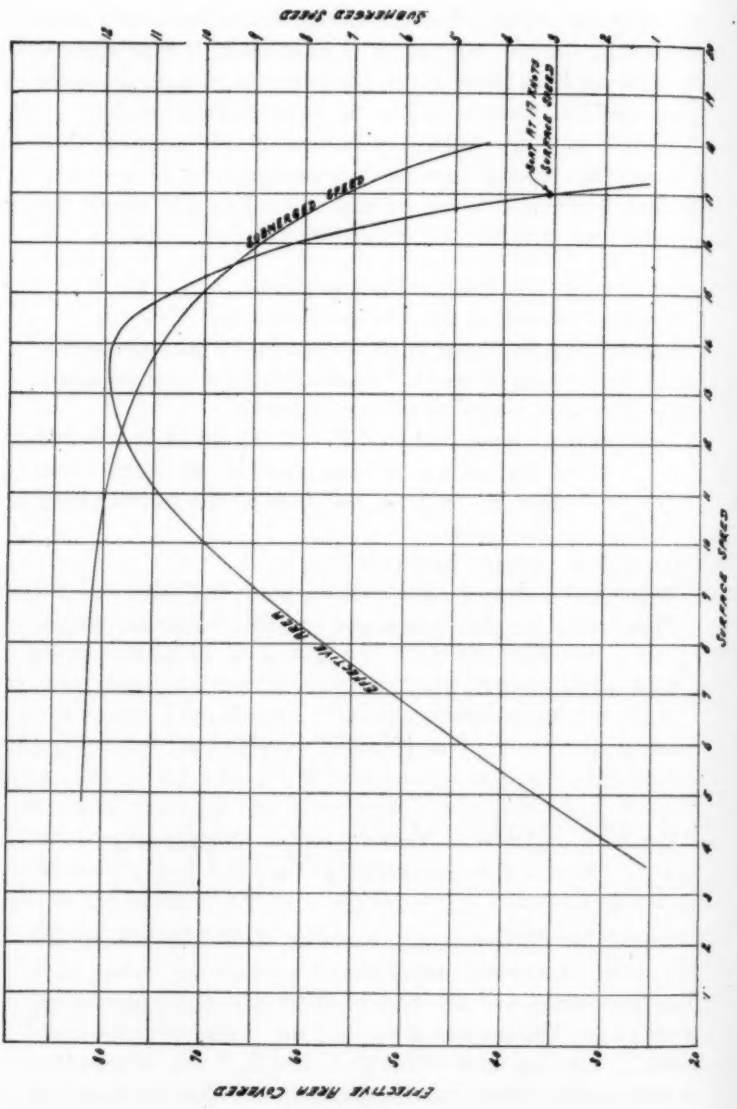

SUBMERGED SPEED
SURFACE SPEED
EFFECTIVE AREA COVERED
SUBMERGED SPEED
EFFECTIVE AREA

Fig. 7.

As an example of the application of this method, data from one of the author's designs is approximately as follows:

$$a = 133$$
$$b = 306$$
$$C_1 = .02$$
$$C_2 = .46$$
$$y = \left(\frac{273{,}000 - 2.60\,x^4}{142.5}\right)^{\frac{1}{4}}.$$

The curves for x and y, and for x and Z, are shown herewith (Fig. 7). The curve of area covered shows a decided maximum, when the surface speed is about 14 knots and the submerged speed 11 knots. If, for this size of boat, the surface speed be made 17 knots, the corresponding submerged speed would be only 7 knots, and the military value of the boat would be less than half of the 14 — 11-knot combination.

As a comparison of boats already built, the following table has been prepared:

Type.	x surface speed.	y submerged speed.	Effective area 1st method.	Effective. area 2d method
Octopus,	11	10	55	510
Laurenti,	14	6	14	120

Both these methods, and every other conceivable rational method, give about the same results and indicate that the general military value of the *Octopus* with high submerged speed is about four times that of the Laurenti with high surface speed.

Considering submerged speed alone as a tactical factor after the submarine has joined issues with the battleship. The variation of probabilities of arriving within striking distance, as a function of the submerged speed, has been previously demonstrated and calculated. By this method the probabilities in favor of the *Octopus* at 10 knots submerged speed average .41, while those of the Laurenti average .27, or 10 to 6.6. (Very nearly proportional to the submerged speed.)

Summing up the above comparison, it will be seen that the *Octopus'* chances for getting into action as compared to the Laurenti are four to one, and that once the issue is joined, her chances of success against a moving target as compared with the Laurenti are 10 to 6.6.

In this European Laurenti type the idea of gaining surface speed at the expense of other essential qualities has been carried further than in any other design. That it has been carried too far in the boat mentioned has already been shown. The extreme of this tendency defeats the *"raison d'être"* of the underwater boat, and puts it in the class of the surface torpedo boat, a type already beginning to go out of fashion. The reasons the surface torpedo boat is losing ground are (1) inability to attack except at night or in a fog; (2) the difficulties inherent to night attacks, such as the difficulty of locating the enemy and the confusion of friends with foes; (3) the increase of power of the torpedo-defense guns of large ships, and the improvements in marksmanship. While the range of the torpedo has kept pace if it has not exceeded the increase of effective range of torpedo-defense guns, the accuracy of the torpedo remains practically unchanged. It would be but a waste of valuable material for a flimsy torpedo boat to use long-range torpedoes when firing at a single moving ship at a distance of 4,000 yards or more. Such ranges are only useful when firing a number of torpedoes into a fleet of the enemy's ships. A boat with such low submerged speed would find itself placed in much the same position, therefore, as a surface torpedo boat. By daylight it would be compelled to submerge, say, five miles distant from the enemy. Now, if the enemy be underway, the chances of getting within close torpedo range where a hit is certain are almost *nil,* because there is not enough submerged speed available. Such a boat would only be effective against an enemy at anchor or in a narrow passage, or by rare chance against an enemy in the open who happened to be approaching it. As for taking part in a fleet action, a boat of low submerged speed need scarcely be considered. On the other hand, a boat with 10 knots submerged speed has some chance to close

with the enemy in a fleet action, while the chances rise rapidly as the submerged speed is increased.

References to the possibility of underwater boats taking part in fleet actions are frequently met with the same smile of incredulity as answered ten years ago to dispose of the idea that they were of any value for anything. A little knowledge of present-day possibilities should eliminate the smile, particularly when it is remembered that fleet actions are never fought in blue water, but always in bays, narrow straits or off the entrance to harbors. The reason is analogous to that which makes the big rivers run through the big cities, since you cannot cook your rabbit until after you have caught him.

Previous Articles in "Journal."

In recent years the JOURNAL has published three articles relating to this subject, one by Lieutenant Halligan, November, 1903; one by Mr. Simon Lake, May, 1906; and one by Major Laurenti, November, 1908.* Historical accuracy and common justice require that some of the errors in those papers should be corrected.

Lieutenant Halligan's article is, in the main, merely descriptive of the Lake type, and as it was written before the speeds, etc., had been accurately determined, it naturally contains unconscious errors, doubtless due to misinformation. For instance, surface speed is set down as 8.57 knots, whereas the actual trial speed was only 7.5 knots. Submerged speed is given as 6 to 7 knots; actual trial speed, 3.8. Submerged endurance given as 20 knots full speed; actual, 8.5 knots. Similar misinformation is manifest when the author had occasion to refer to the "diving type," meaning the Holland type; the most startling instance being the statement that the periscope showing life-size images had a field of only 1 degree 48 minutes, the facts being that the field was about 30 degrees. The author's deductions as to the use of the instrument were, therefore, of course, utterly valueless.

* Reprinted from "Cassiers Magazine"

Major Laurenti's very interesting article covers a wide field, and is generally of a descriptive character. Although containing a number of expressions of opinion, with some of which the writer is not in agreement, certain mistakes as to facts have crept into the article, one or two of which it will be well to correct.

On page 933, Major Laurenti states that forms based on spindles of revolution have a tendency to depression of the stern, both on the surface and submerged, and, further, that this was modified in the case of the *Shark* by an initial depression of the bow brought about by water ballast. The remark is illustrated by a photograph (page 936) purporting to show the still trim of the *Shark*. As a matter of fact, the boat shown in the photograph is not the *Shark* at all, but the *Fulton*. This is, however, beside the mark. The point is that he has mistaken the bow for the stern, and the photograph is in direct conflict with his text, which is itself entirely erroneous. That vessel never had any tendency to depress the stern, nor was it found on trial, as stated by Major Laurenti, that the diving rudders had to be operated to raise the stern; on the contrary, so far as they were used at all, it was to hold the stern well under at a certain speed where the wave formation changes, it being found that better speed was attained that way.

On page 935 it is stated that the buoyancy of American boats is about 10 per cent. Even the earliest boats (*Adder* and *Plunger*), with the smallest percentage, had from 15 per cent. to 16 per cent.; the later ones have more. In pursuing, it may be remarked that the actual cruising performance last summer of one of these early boats, the *Plunger,* is not consistent with the idea that her surface qualities are in any way defective.

On page 946 it is stated that battery elements exceeding one ton in weight have been used in American Holland boats. Nothing like that weight has been employed. Moreover, the maximum weight to be handled in installing or dismantling is only 60 pounds, and all parts pass readily through the hatches. The criticism is singularly misdirected, as, without doubt, the battery installations in question are superior to all other sys-

tems in simplicity and accessibility, and are easier to dismantle and repair.

The remaining article, that by Mr. Simon Lake, is extremely controversial in tone, and is principally devoted to the exploitation of the Lake type at the expense of the "so-called" Holland type.

On a false foundation Mr. Lake erects a curious superstructure of mingled fact and fancy, and caps it with some very sweeping claims of superiority in submerged qualities. Much of the structure consists of wide statements of alleged facts with respect to "diving" boats. The premises above noted and some of the sequels are interesting and would doubtless be important, except for the fact that they are inaccurate. It will be conceded that the absence of accuracy somewhat impairs their value as component parts of the structure, and that their extraction would topple it to the ground.

Lack of space here prevents traversing the paper completely, but it is proposed now to select a few salient features for comment and correction.

Let us start with the essential basis of the paper. We quote this statement by Mr. Lake:

"The *sine qua non* to the successful working of the diving boat is extreme sensitiveness in a fore-and-aft direction when submerged, or, in other words, lack of longitudinal stability. Without this tenderness it is practically impossible, at the speeds so far attained, to control such a vessel when running submerged."

Now for the stubborn and contrary facts. The *Protector* class of Lake submarines (170 tons displacement) had a submerged metacentric height of 7.3 inches, while the Electric Boat Company's type *7-P* (122 tons displacement) had just 64½ per cent. more, notwithstanding its smaller dimensions. As officially determined at Newport, the *Octopus* (273 tons) had 72 per cent. more than the Lake (230 tons), and the Board reported as follows: "The *Octopus* has a distinct superiority over the Lake as regards submerged stability in that she is not only larger, but has a greater metacentric height in the

submerged condition." These figures, the result of carefully conducted tests, authentic, reliable and incontrovertible, remove at one sweep the above-quoted basis of Mr. Lake's argument, as well as his corollary, viz: that his designs have a "far greater measure of longitudinal stability than it is possible to secure in the diving class."

We quote again:

"To run 'awash,' therefore, it is necessary to trim by the stern and, still further, to offset any tendency to plunge by setting the horizontal rudder a number of degrees to 'rise.'" .

On the contrary, it is not *necessary*. The diving boats of the author's designs are not "trimmed by the stern" to run awash, and the diving rudder is not "set to rise." The boats have no tendency to plunge.

It is interesting to note here the disagreement between Drs. Laurenti and Lake. The former would have us believe that the type criticized is faulty in that it naturally takes an inclination "by the stern," while the latter's complaint is that an inclination "by the bow" is present. Now, if applied to some special case it is conceivable that one, but not both, of the criticisms might be justified. However, as applied by these gentlemen in a general statement, it is obvious not only that both cannot be true, but that neither is necessarily so.

Again:

"To dive, additional water is admitted into what is called the forward trimming tank, the horizontal rudder is set to 'dive,' and the vessel plunges under, head first, like a porpoise. Now, the trick in handling a diving boat is to allow her to reach a depth of several feet below the surface—where the down-pull at the bow is less—and then to catch her and hold her at that submergence by the *continual* manipulation of the horizontal rudder."

On the contrary, no water is admitted to the forward trimming tank, or any other tank, and no change is made in the disposition of internal weights or ballast, and continual manipulation of the horizontal rudder is not required.

So much for basic facts illustrating the expert character of

the evidence. Turning for a moment to theory, Mr. Lake's Figs. 1, 2, 3 and 4 are reproduced for reference in Fig. 8. Leaving aside for a moment the anomaly of treating the problem of submerged control as a statical one, let us examine the beam illustration, Fig. 2, wherein Mr. Lake represents the forces acting on the diving boat as follows: *A*, the center of buoyancy. *B*, the weight of boat at the center of gravity, acting to hold the beam horizontal. A heavy weight *F* at the bow representing a mysterious "down pull." *T*, at the stern a weight representing the downward component of the pressure on the "rising rudder" *C* and *H* the "very small reserve buoyancy" an upward force of only 1/560 part of the boat's weight. This is the only upward force represented as acting on the beam. Now, if the facts were as stated, the system would not be in equilibrium as represented, since the little force *H* would be overcome by the sum of *F* and *T*, represented by Mr. Lake as much larger forces, and the boat or beam must inevitably sink on an "even keel."

Now let us correct the illustration by placing the diving rudders in the opposite direction *i.e.*, "to dive;" then *T* becomes an upward force, helping *H* to support the boat, but coöperating with the mysterious and mischievous "down pull" *F* to incline the boat down. The inclining effect, then, of *F* is just doubled, and, according to the theory developed by Mr. Lake, the boat must take a severe inclination by the head, and proceed rapidly to Davy Jones' locker. Now, unfortunately for the theory, neither the diving boats which carry a "rising rudder" nor those which carry a "diving rudder" behave in this way. The obvious conclusion is either that the mysterious "down pull" is non-existent or negligible, or else there are other controlling factors in the problem omitted by Mr. Lake. Either solution leaves the illustration in a sorry shape as a support to the argument.

The next division of Mr. Lake's paper enumerates six forces which he considers to be acting on the submerged vessel, balance between which he states can only be achieved under chosen conditions and by exceptional skill at the diving rudder. This

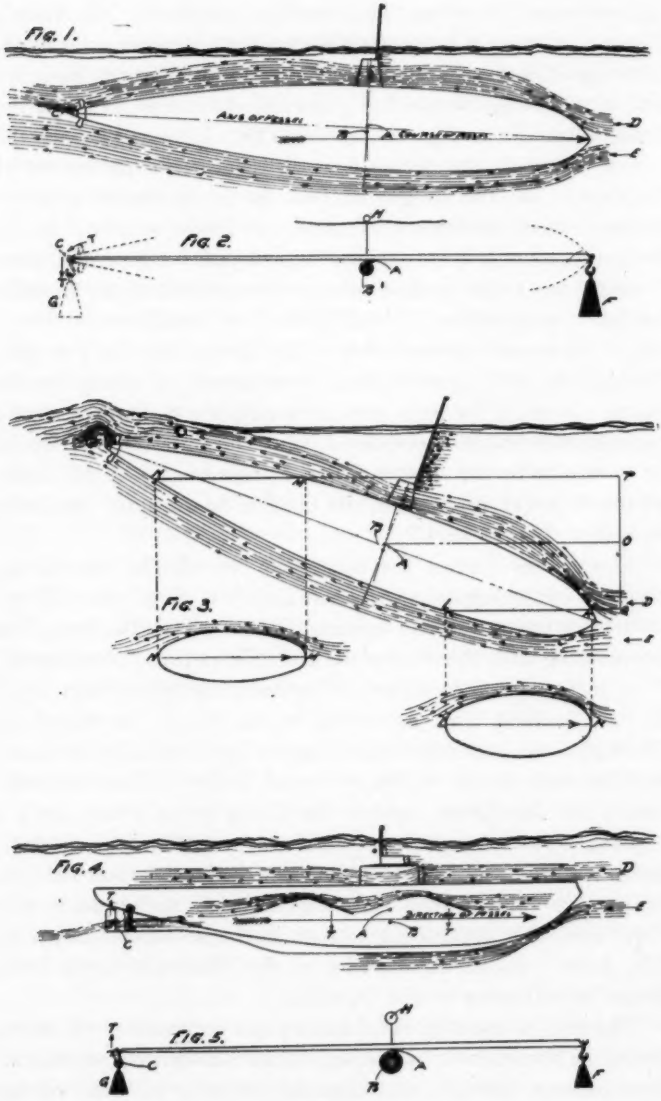


Fig. 8.

conclusion flies in the face of well-demonstrated facts set forth in many official and unbiased reports accessible to any seeker after the truth. As Mr. Lake has had no opportunity to acquire the facts first hand, it would be interesting to know by what method, except false reasoning based on misinformation, he reaches this conclusion. The illustration which he cites—the British *A-4*—is certainly amusingly wide of the mark. Mr. Lake neglected to inform himself, or at least to state the salient fact, that *A-4* was not under way when the accident happened, and hence the forces of which he speaks could have nothing to do with the matter. The facts are that *A-4* was lying at rest in the submerged condition, with practically no buoyancy, engaged in a test of submarine signals. An open ventilator projected above the water, through which a flag was being operated from the interior. A passing wave submerged the open ventilator, admitting water to the interior. On account of the flagstaff it was impossible to quickly close the ventilator; hence, when sufficient water had entered to destroy the buoyancy the vessel naturally sank, and the inrush of water increased with the depth and pressure. The water, having a free run in the boat, naturally sought the lowest level—in this case the bow, and naturally again produced an inclination. What all this has to do with the forces acting on a boat under way, the shape of the boat, the diving rudder, etc., passes the ordinary comprehension. It is in the same class as the oft-cited deep submergence of the *Porpoise,* elsewhere dilated on by Mr. Lake. Here, again, the vessel was not under way and sank merely because her weight exceeded her displacement, obeying a law of nature which makes no exceptions in favor of any particular design or type of boat.

The balance of Mr. Lake's criticism is of much the same order, viz: the vigorous belaboring of a man of straw. Space forbids a detailed discussion, but the reader, if interested, is referred to Mr. Lake's text and his Fig. 3. The stream lines therein shown are purely imaginary, and, moreover, not consistent with the text, which assumes that the center of gravity of the vessel is moving along the horizontal line *A-O,* while

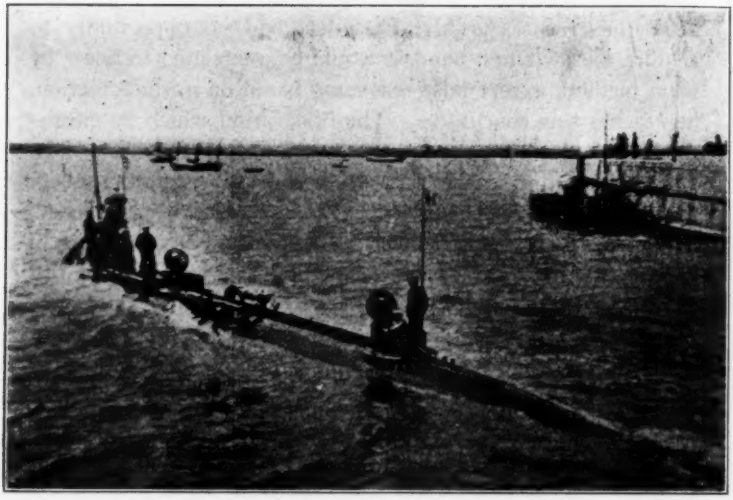


Fig. 9.—"LUTIN," FRENCH, SUBMARINE PROPER. SURFACE CONDITION.

Fig. 10.—"OTARIE" FRENCH, SUBMARINE PROPER. SURFACE CONDITION.

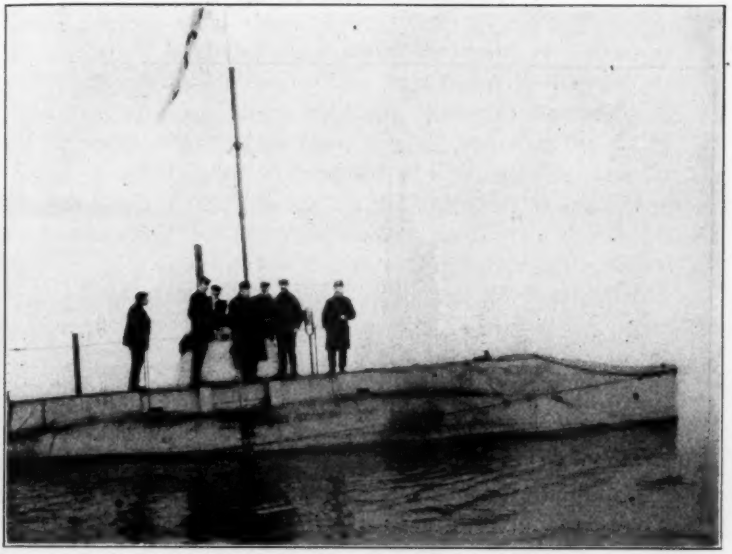


Fig. 11.—Luctor Electric Boat Company's Type "7-P." Rest Surface Condition.

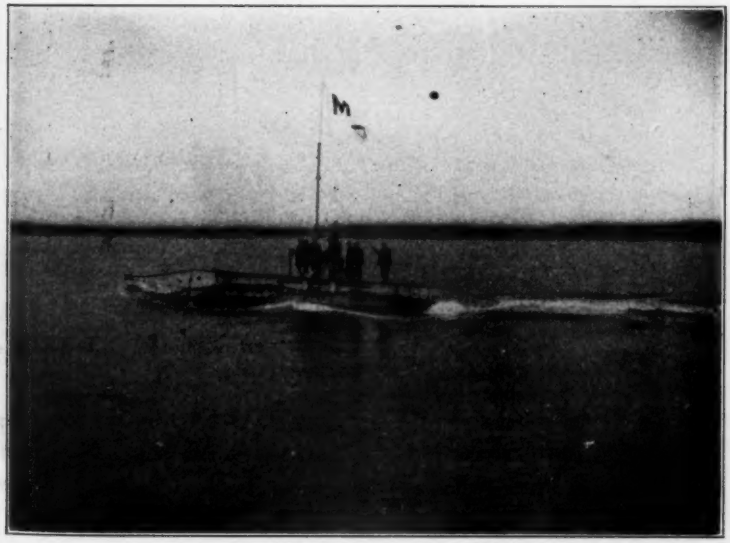


Fig. 12.—Luctor Electric Boat Company's Type "7-P," Full Speed. Surface Condition.

Fig. 13.—Electric Boat Company's "Octopus" at Rest. Surface Condition.

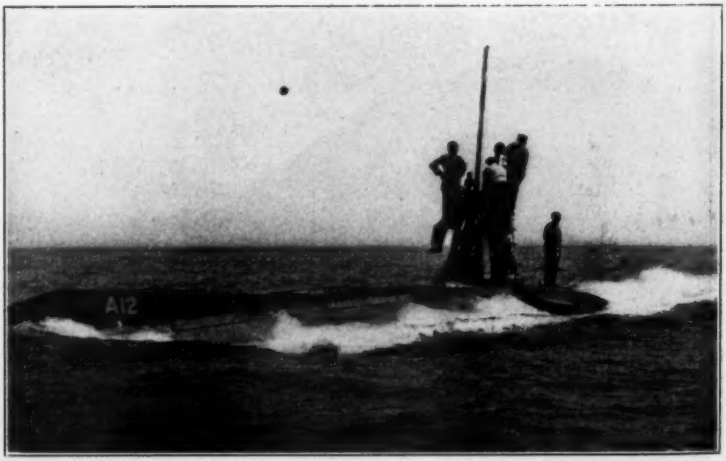


Fig. 14.—British "A-12" Under Way, Full Speed. Surface Condition.

an oscillation is taking place about the point *A*. Even as drawn, however, the conclusions are vitiated by the *unwarranted* assumption that the resistance offered to the oscillation by the upper after-surface from *A* to *C*, including the diving rudder, is less than that forward of *A*, tending to increase the angle. That is, the essence of the argument is erroneous, hence also the conclusions, as has been demonstrated not only by years of practical service, but by special experiments, where, after giving the boat an inclination down, the diving rudder was set at zero and abandoned. If the theory were true, an

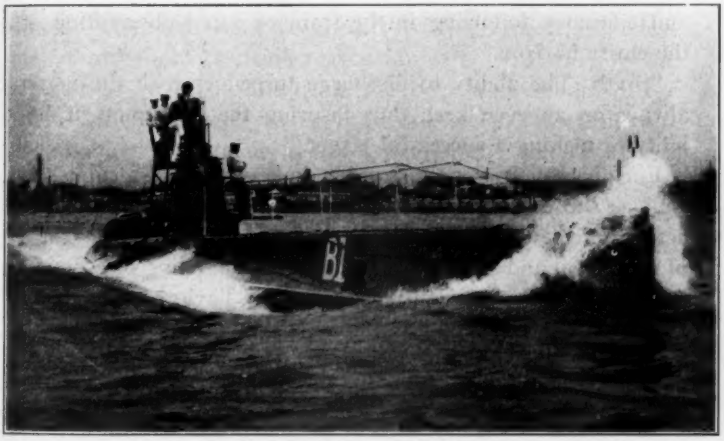


Fig. 15.—British "B-1" Under Way, Full Speed. Surface Condition.

enormous angle and a disastrous plunge must have resulted. The facts are that the angle and depth reached were always very moderate. The boat always automatically checked itself and returned to the surface.

Mr. Lake concludes his article by an analogous line of reasoning with respect to his designs, concluding as follows:

"The practical results thus secured by the 'submersible' (meaning the Lake design) are:

"First. Safety in submerged control.

"Second. Facility in handling that calls for no special train-

ing or rare dexterity on the part of a single member of the crew.

"Third. Easy maintenance of a uniform depth on an even keel in waters of variable depths, thus making it safe and practicable to operate either in deep or shallow waters.

"Fourth. The removal of restraint to free movement on the part of the crew in the *very fullest* discharge of their duties.

"Fifth. By preserving an even keel, insuring the effective operating of the observing instrument the moment it appears above the surface, and thus affording that measure of safety and efficiency following in the train of rapid observation of the entire horizon.

"Sixth. The ability to discharge torpedoes with the vessel always on an even keel, thus insuring the maximum probability of making a successful target."

Fortunately, it is now possible to test these assertions, as well as the criticisms of the "diving" types, by the results actually achieved in practice as reported by an official board of competent and impartial naval officers consisting of Admiral Adolf Marix, Naval Constructor D. W. Taylor, Commander B. T. Walling, Lieutenant Commander William Strother Smith and Lieutenant John W. Timmons, who, in May, 1907, conducted an exhaustive series of competitive tests between the diving boat *Octopus* and the *Lake,* which latter was the latest example of the so-called "submersible," above described by Mr. Lake. The boat was completed in 1906, so that ample time had elapsed for practice and for alterations. Both boats, prior to their trials, were officially certified by their owners as being *complete* in all respects and ready for trial. In the appendix will be found the trial program.

Reference has been made above to the determination by the Board of the relative submerged stability of the *Octopus* and the *Lake,* showing the former to have 72 per cent. more, and effectually disposing of Mr. Lake's "*sine qua non*" of a successful diving boat, viz: lack of submerged stability.

As to the relative merits of the submerged control, the facts

again speak for themselves. During the competitive trials the diving type, as represented by the *Octopus,* was controlled with the greatest ease and at all times maintained her depth satisfactorily. The *Lake,* as the representative of the "even-keel" type, was a complete failure so far as submerged control was concerned. In this connection attention is invited to the fact that the conditions of speed were most favorable to the *Lake,* as her submerged speed was only 5.65 knots, while that of the *Octopus* was almost double this, viz: 10 knots. On her first trial the *Lake* was entirely beyond control, and behaved so badly that the motors had to be stopped to allow her to settle down. The trial board declined to continue the trials unless the control could be made reasonably safe. Contrary to the regulations governing the trials, the *Lake* was withdrawn for alteration. The stern diving rudders were increased in area and changes were made in the hydroplanes. But even with these improvements the *Lake* remained a failure so far as submerged control was concerned. Control by the hydroplanes was abandoned, these being set at a fixed angle, and the boat handled by the diving rudder. She was thus controlled by exactly the same method as that used in her rival of the "diving type." But, due to certain other features, even after employing the correct principle, complete control was never obtained. During the speed trials she broached to the surface fourteen times and carried the flag under twenty-seven times. The variation in depth was from ten to twenty-one feet, and in fore-and-aft trim from three degrees up to nine degrees down. It was perfectly obvious to any observer that the speed, low as it was, was still too high to be used under service conditions with this type of boat, for the reason that the boat could not be controlled. With a lower speed the control was better. Compare this with the *Octopus,* which at 10 knots varied only two feet and changed only one degree in trim. It should be noted in passing that even during this high-speed trial members of the Board and crew were moving freely about the boat.

The Board summarizes the facts as follows:

"*Submerging.*

"Starting with the vessel at cruising speed, to pass to the submerged condition, including sealing the boat and trimming for diving, required in the case of the *Lake,* 7 minutes and 19 seconds, and in the case of the *Octopus,* 4 minutes and 45 seconds.

"The time required to come to the surface from a depth of 30 feet and to return to that depth was, in the case of the *Lake,* 1 minute and 2 seconds, and in the case of the *Octopus,* 40 seconds.

"The maximum slant down in performing this evolution was 12 degrees in the case of the *Lake* and 11 degrees in the case of the *Octopus.*

"*The Board observed with great care the behavior of the two boats when submerging and running submerged with reference to the important question of change of trim and the control of level.* At no time did the *Lake* submerge upon an even keel. To get her under water it was necessary to raise her stern with the diving rudder and allow her to go down at an angle, as in the case of the *Octopus.* The control of level and of trim under water was distinctly superior on the part of the *Octopus.* The hydroplanes of the *Lake* were not used to submerge her, but were set to the angle considered desirable by the operator before submergence, and vertical control under water was obtained entirely by the use of the horizontal rudder. During the submerged speed trial and the submerging trials the forward pair of hydroplanes had been removed entirely.

"The large, flat superstructure deck of the *Lake* is considered objectionable, for the reason that it renders the control of the vessel when she is submerged much more difficult as soon as she departs from the even-keel position. The fact that the diving rudder, periscope and hydroplanes are all handled in the conning tower by one and the same man is also considered objectionable and dangerous, it being advisable to have at least the diving rudder and periscope worked by different persons. In the *Octopus* the man at the diving rudder has a comfortable

station and can do his work thoroughly and without distraction, which is not possible for the man in the *Lake* under the present arrangement."

The Board's final conclusions as to the relative merits not only of the two boats, but of the "types," is expressed as follows:

"1. That the *type* of submarine boat as represented by the *Lake* is, in the opinion of the Board, inferior to the *type* as represented by the *Octopus*.

"2. The closed superstructure of the *Lake*, with the large flat deck, which is fitted to carry water ballast and to contain fuel tanks and air flasks, which is an essential feature of the *Lake* boat presented to us for trial, is inferior to the arrangement on board the *Octopus* for the same purposes, and also is, in the opinion of the Board, detrimental to the proper control of the boat.

"3. The hydroplanes, also an essential feature of the *Lake* boat presented to us for trial, were incapable of submerging the boat on an even keel. They are therefore regarded as an objectionable encumbrance."

This demonstration was declared officially by the Board on Construction and by the Navy Department to be "*complete and conclusive*," and would appear to dispose pretty effectually of the extraordinary claims set forth by Mr. Lake.

With reference to surface qualities, the Board reported under caption "Sea Trials"—

"There was no marked difference in the behavior of the boats in a seaway."

Nowhere in the report or in any other official report of trials of the *Octopus* or like ships is any reference made to any unsatisfactory behavior on the surface or submerged, nor is there anywhere any hint as to any danger of unexpected dives. As indicating comparative conditions reference may be made to photographs taken during these trials. No. 21 shows the *Octopus* proceeding at 8½ knots speed, No. 20 the *Lake* at 7.59 knots (her maximum), and No. 22 the *Octopus* at 11 knots. It will be observed that the *Lake* is down by the head

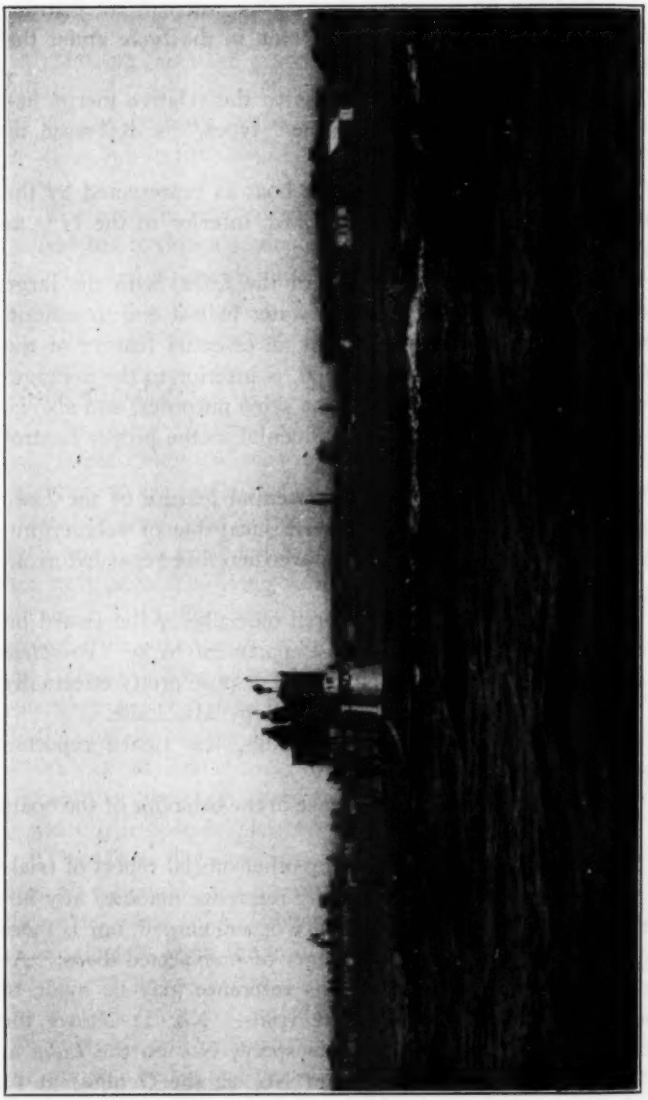


Fig. 16.—British "C-1" Under Way, Slow Speed. Surface Condition.

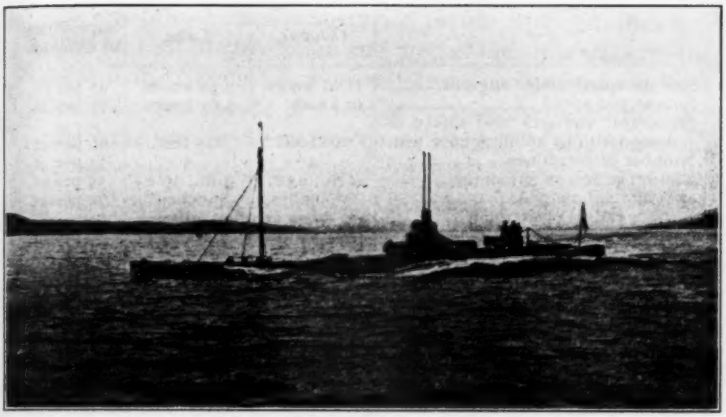


Fig. 17.—Krupp "Equevilley's" Type Under Way. Surface Condition.

and the forward deck covered by water. To the casual observer she would appear to be in more danger of diving than is her rival. The photographs are also of interest as showing graphically the relative freeboard and buoyancy of the two vessels on the surface.

In every quality which could be measured and indicated by figures the *Octopus* showed marked superiority, the percentages of which are set forth below:

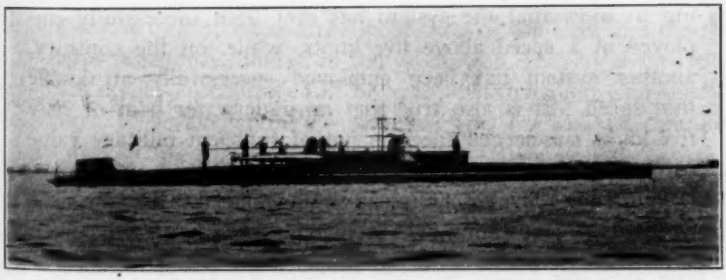


Fig. 18.—French "Aigrette," Laubeuf Type, at Rest. Surface Condition.

—	*Octopus.*	*Lake.*	Superiority of *Octopus.*
Surface speed under engines.....	11.02 knots.	7.59 knots.	45 per ct.
Submerged speed	10 knots.	5.65 knots.	77 per ct.
Structural strength and safety as demonst'td by submergence test.	200 feet.	125 feet.	60 per ct.
Number of torpedoes.....	4	3	33 per ct.
Time required to submerge.....	4 m., 45 s.	7 m., 19 s.	54 per ct.
Stability submerged.....	13¾ inches.	8 inches.	72 per ct.
Surface radius of action †.....	680 miles at 935 knots.	395 miles at 7.25 knots.	70 per ct.
Submerged radius of action at 5.65 knots.....	76.5	17	350 per ct.

†Note that the surface radius is determined for a much higher speed of the *Octopus* than for the *Lake*. A proper comparison is on the basis of the same speed. In this case the radius of the *Octopus* at 7.25 knots is 1,120 miles, or 183 per cent. superior to the *Lake*.

At these trials the *Lake* represented exactly the designs so widely advertised as superior to all others. Subsequently the vessel was modified, as shown in Fig. 20, an inspection of which will show great resemblance to the general above-water form of the *Octopus*. The modifications are reported to have improved her submerged control, but on the demonstration no record was taken of speed. It was hence of no special value, since it has long been known that at low speeds, where the forces acting are comparatively small and the time required to produce changes of depth due to inclinations of axis comparatively great, it is practicable to secure satisfactory control by the "hydroplane" system. It is also a fact that at the present writing there is no trustworthy official evidence existing to show that the system has ever been successfully employed at a speed above five knots, while, on the contrary, another system has been employed successfully at double that speed. It is also true that an underwater boat of only five knots submerged speed is not of sufficient military value to justify serious consideration.

While the above discussion has been confined to a comparison of the Lake so-called "hydroplane" system of submerged control as compared with the simple stern-diving rudder system, it must not be thought that the author advocates the latter system under all conditions. For, while it has con-

clusively proved its supremacy for vessels up to 300 tons displacement, of proper design and proportions, it is quite on the cards that some modification will prove necessary, or at least desirable, for vessels of increased displacement, particularly where the form and proportions are dictated by considerations of higher surface speed, with a corresponding sacrifice of submerged qualities. A brief discussion of the general subject would therefore appear to be in order.

GENERAL CONSIDERATIONS GOVERNING SUBMERGED CONTROL.

Type of Diving Apparatus.

All modern submarines normally submerge with a reserve of positive buoyancy, and for submergence and control when under way employ some kind of horizontal inclining planes, the angle with the direction of the flow of water being capable of control. The planes can thus be used to produce a thrust perpendicular to the horizontal plane passing through the longitudinal axis of the boat. When this thrust does not pass through the center of gravity of the vessel the planes are horizontal rudders, which produce, in addition to the vertical force, a turning moment about the center of gravity, which is used to control the inclination of the axis. When this thrust does pass through the center of gravity the planes cease to be rudders and are termed submerging planes, hydroplanes, etc. They cannot be used to control the inclination of the axis, and their useful function is limited to the production of vertical thrust. Such planes, of course, must be so located that their combined center of action is in the same vertical line as the center of gravity.

Horizontal rudders may be located either at the stern or at the bow, or at both places. In the first two cases simple rudder action is involved, that is, a vertical thrust and a turning moment. In the last case the resulting action will vary with the method of use. Thus, if the bow rudder is set to depress the bow and the stern rudder to elevate the stern, the resulting

vertical thrusts may be eliminated by neutralization, leaving a true turning moment to control the inclination of the axis; or, if both rudders be inclined in the same direction, the turning moment may be eliminated, leaving a simple vertical thrust. Variations between these extremes can be secured by altering the angle of one set so as to produce both turning moment and vertical thrust when desired.

(*a*) Where stern or bow rudders alone are used it is the intent of the design to produce and control submergence by controlling the inclination of the axis and to effect changes of level by steering the vessel down or up inclined curves.

(*b*) Where submergence planes are used it is the intent of the design to maintain a horizontal axis and to effect changes of level by forcing the vessel bodily down or up, down by the excess effect of the planes over the reserve buoyancy, and up by the excess of the reserve buoyancy or by the addition of the two forces. Or it may be the intent to use such planes to neutralize the reserve buoyancy, change of level being obtained by inclination of the axis under rudder forces.

(*c*) When both bow and stern rudders are fitted it is the intent of the design to provide, first, additional turning moment for control of the inclination of the axis, or, second, additional thrust rightly directed to aid changes in level when it is desired to effect such changes with a minimum angle of inclination.

Assuming for the moment a successful application of these systems, then in the case of (*a*) the method of operation would be pure "diving," and in the case of (*b*) "even keel." In the case of (*c*) optional between pure "diving" and a combination of "diving" and "even keel."

As a matter of fact, it is impracticable to construct a boat which will operate (particularly at high speed) on an exactly level keel, since disturbing forces, both exterior and interior, are absolutely unavoidable, and there is, of course, a practical limit to the stability which can be secured to resist them. Therefore some angle of inclination is inevitable, even at the very low speeds heretofore attained by this type. Such vessels

always carry a rudder to control inclination, and at high speeds its constant use would appear almost inevitable.

As corrected by practical considerations, then, it would appear that in operation the difference between (*a*) and (*b*) would be a difference in angles of inclination of axis of boat used, other things, such as buoyancy, speed, power, etc., being equal, while (*c*) would normally employ angles between the two, but nearer to (*b*), while retaining the power to increase angles at will as might be desirable when rapid changes of level were wanted, or as might be necessary in emergencies to overcome abnormal disturbing forces.

With regard to mechanical simplicity, protection to the planes and resistance, (*c*) is superior to (*b*), and as it is a more useful arrangement than (*b*) even for speeds to which the latter might be applicable the choice should be limited to (*a*) and (*c*).

Simple stern rudders have the advantage of great mechanical simplicity, good protection against external damage, small resistance and ease and simplicity of operation. The adequacy of control and the rapidity and certainty of the vertical maneuvering powers so secured have been fully demonstrated by many vessels built by the Electric Boat Company. Therefore, on account of the advantages above cited, this method is adopted when the conditions are suitable. Briefly, these conditions are fixed by the form and dimensions of the hull, moments of inertia, the position of the center of gravity, buoyancy and resistance, the location of shaft centers, power employed and speed attained. When the combined effect of these conditions becomes too unfavorable it is necessary to add bow rudders and to accept with them the disadvantages involved, viz: increased resistance and complexity, and decreased protection, gaining an increase in control of inclination and the ability to operate with smaller angles when desired. The point where the change becomes necessary cannot be determined exactly upon theoretical grounds or from experimental data, unless the latter be obtained from a full-sized boat, and it is thus a matter for the designer's judgment as influenced by the main tendencies at work.

Motive Power.

The *main engines* for surface cruising are a very important element in the design of a submarine.

Owing to the fact that gasoline will evaporate rapidly at or below atmospheric pressure and at or below ordinary atmospheric temperatures, it is much the easiest form of liquid fuel to employ in an internal-combustion or explosive engine, since the problem of filling the engine cylinders with the proper mixture of vapor and air to secure complete combustion is comparatively easy. Unfortunately, this very quality renders the fuel dangerous when employed in closed spaces, as it necessarily is in a submarine. When storage tanks are not entirely filled the air above the fuel rapidly becomes saturated with vapor, which is materially heavier than free air. Should this gain access to the interior of the boat it will first settle to the bottom and then gradually diffuse, so that at some stage a rapidly-inflammable (or so-called explosive) mixture of vapor and air will be formed. The same conditions arise when liquid gasoline, even in small quantities, gains access to the interior of the boat, and, as the mixture is explosive within the limits of eight to twenty parts of air to one of gasoline, its presence in an enclosed space containing a great quantity of electrical apparatus would undoubtedly be highly dangerous. Through proper precautions in design, construction and operation this can be reduced to permissible limits, but it cannot be entirely eliminated, particularly in the event of damage to the structure or fittings of the boat, through collision or otherwise.

These considerations apply not only to the boat itself, but also (and perhaps with greater force) to the tenders and other stations supplying fuel to the vessels, as here the necessary precautions are more apt to be neglected.

While this question of safety has been the main consideration leading to the development of motors not requiring the use of this fuel, it should be remembered that gasoline has collateral disadvantages, viz: the supply is limited, the demand constantly growing, the price is high and increasing, the distribu-

tion is uneven and uncertain, and the content of heat units comparatively low. This means not only a high fuel cost for operation, but, on account of the uncertain supply and distribution, further expenditures are necessary to provide an adequate supply when and where wanted.

To insure absolute safety under all conditions the fuel must be of such a character as not to give off inflammable vapors at atmospheric pressures under the temperature conditions existing in the storage tanks and interior of the boat. Kerosene fills these conditions admirably, and a good grade of this oil with a high flash point can be stored and handled in a submarine or its supply station without risk of explosion, even under damaged conditions. This fuel also fills the required conditions as to supply and distribution, being easily obtained in all parts of the world, and as the heat content is greater and the unit price less than gasoline, the cost of operation is materially reduced, while with a given weight of fuel the number of H.P. hours obtainable is greater. These great advantages would long ago have led to the adoption of this fuel for submarines had suitable engines been obtainable, and has led to an enormous amount of experimentation and development work in this direction, which has only recently borne fruit in large units of power. Most of the attempts have been in the line modifying the ordinary Otto cycle gasoline engine so as to supply the necessary heat to the fuel to produce evaporation when and where desired, the compression pressure in the cylinders being suitably reduced on account of the fact that a kerosene mixture will pre-ignite at a lower pressure than a gasoline mixture. This problem may be approached in two ways: first, by supplying heat to the oil in the vaporizing or mixture chamber by means of the exhaust gases; or, second, by injecting the fuel into the cylinders during the suction stroke, the vaporizing heat being supplied by a hot valve or other special parts inside of the cylinder. In either case the temperatures must be held within certain well-defined limits, otherwise combustion is incomplete and working parts become clogged with a hard, carbon-like substance, preventing efficient

service. Such control of temperature has proved almost impracticable, particularly in large cylinders. In addition, the reduction in compression reduces the power of the engine from 10 to 30 per cent., as compared with gasoline, and there is no gain, but rather a loss, in the weight of fuel required per H.P. hour, notwithstanding the greater heat-unit content of the fuel. These difficulties, inherent in the problem and general in their nature, have largely confined such engines to small units for special purposes where frequent disassembling and cleaning is feasible. Only two examples of this general type of engine have ever been developed for and installed in submarine boats, viz: the Thornycroft and the Korting. Both types of engines have disadvantages connected with the question of starting. Such engines cannot possibly start on cold kerosene, and require the engine proper and the vaporizer to be well heated up. Only two methods are practicable for this: first, to start the engine on gasoline or other volatile fuel and run until the proper temperature has been obtained; or to turn the engine with exterior power and heat the air supply, no fuel being admitted until the proper tempearture is reached. The Thornycroft engine starts by the first method, and hence involves carrying a supply of gasoline. As the danger from gasoline arises from leakage of small amounts, the prime object in employing heavy oil, viz: safety, is defeated, and on account of comparatively high fuel consumption no collateral advantages are gained except some reduction in fuel cost. The Korting employs the second method. The engine is turned over by the main motor for about ten minutes, the air supply being heated electrically. This has obvious disadvantages, aside from the delay in starting, viz:

(*a*) With the batteries out of commission or exhausted the engine cannot be started at all.

(*b*) Life of the battery is shortened by this extra use.

(*c*) Every start of the engine requires a partial recharge of the battery, or else involves a loss of submerged endurance and speed.

(*d*) An unavoidable loss of submerged endurance and speed

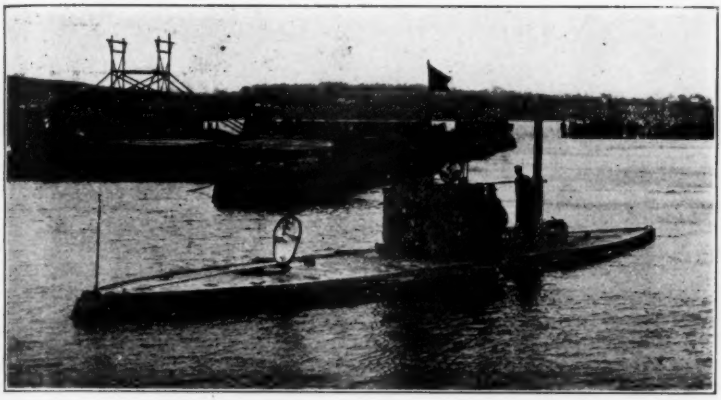


Fig. 19.—"LAKE" AT REST. SURFACE CONDITION.

is caused by the fact that a sufficient charge must be left in the battery at the end of a submerged run for starting the engines.

This engine, being of the two-cycle type without valves, is probably less apt than the Thornycroft four-cycle engine to be incapacitated by the products of incomplete combustion. On the other hand, it cannot be built in such large units on

Fig. 20.—"LAKE". UNDER WAY, FULL SPEED. SURFACE CONDITION. 7.59 KNOTS.

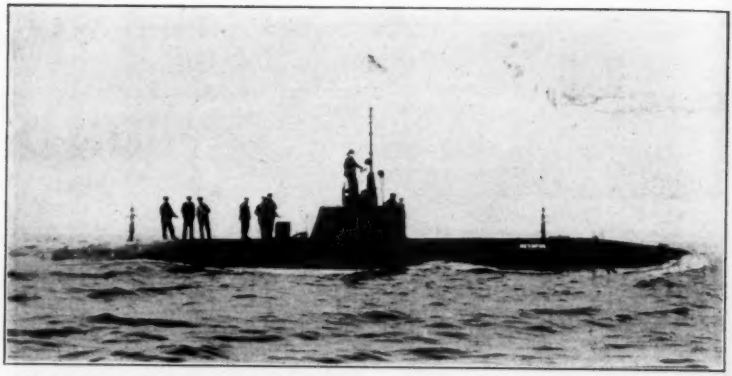


Fig. 21.—Electric Boat Company's "Octopus" Under Way, 8½ Knots. Surface Condition.

account of the cooling difficulties inherent in the design. The fuel consumption is about the same, so that the above remarks as to collateral advantages apply here also.

These disadvantages have naturally led investigators to turn their attention to other cycles than the Otto; for instance, the Diesel, where preliminary vaporization, compression of gas mixture, electric ignition and explosion are dispensed with

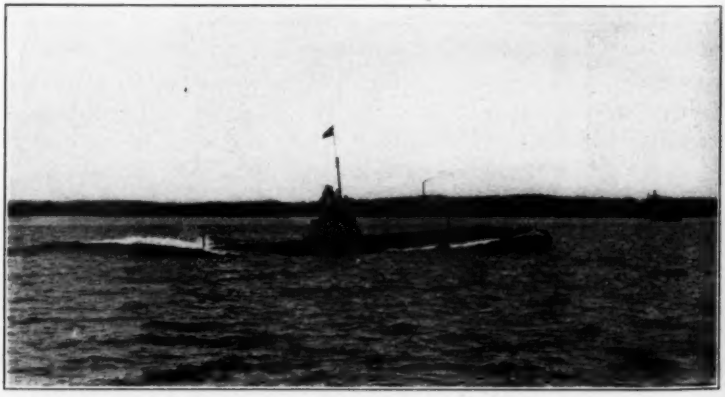


Fig. 22.—Electric Boat Company's "Octopus" Under Way, Full Speed, 11.02 Knots. Surface Condition.

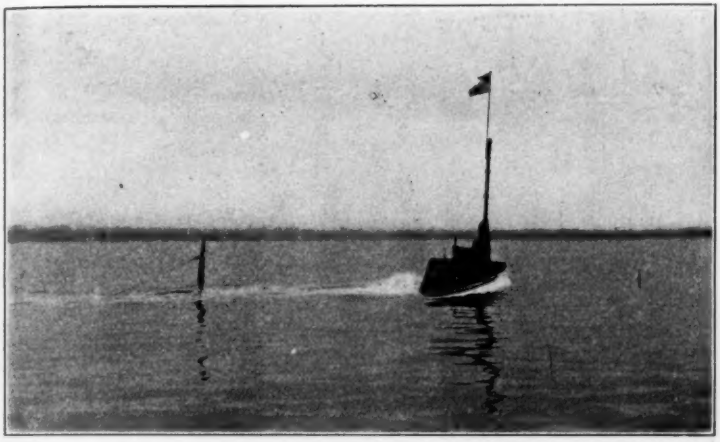


Fig. 23.—"Octopus" Diving.

entirely and replaced by compression of air in the working cylinders to a high pressure and a temperature above the burning point of the fuel, which is injected in a spray at the top of the stroke and so vaporizes and burns in an excess of air without explosion, the pressure in the cylinder never rising above the compression pressure. This cycle has never been generally applied to marine propulsion, although its advantages, ecenomy, etc., for land installations have long been

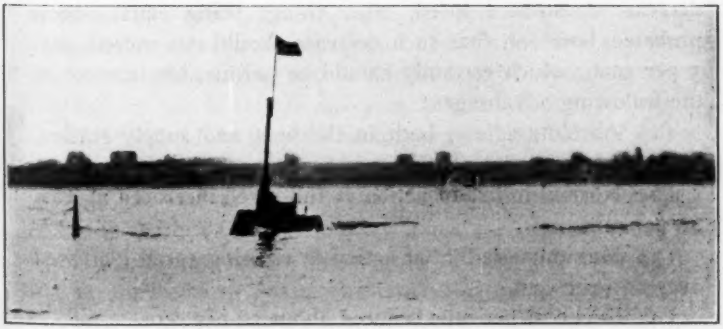


Fig. 24.—"Octopus" Rising From a Dive.

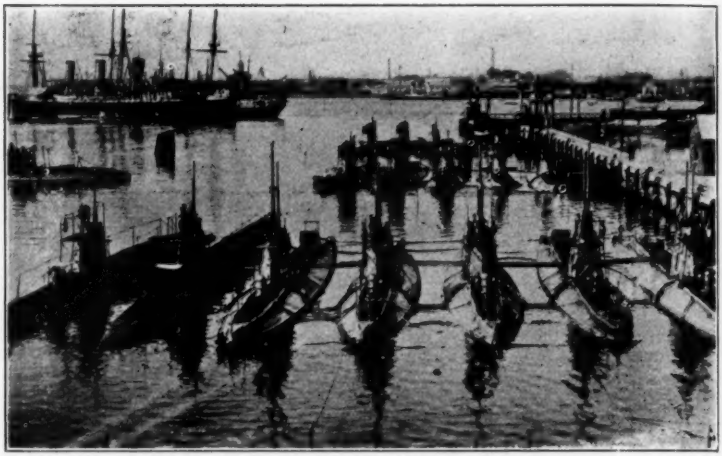


Fig. 25.—FLOTILLA OF BRITISH SUBMARINES.

known. The excessive weight and space involved in land installations, due to high pressures and low speeds, have been prohibitive for marine use, and those disadvantages will have to be measurably overcome before such engines can be successfully applied to submarine service.

With the same allowance of space and weight for such an engine it apparently will never be practicable to secure as much power as with gasoline engines, hence its use means a decrease in surface speed, other things being equal. It is probable, however, that such decrease should not exceed, say, 5 per cent., which certainly should be permissible in view of the following advantages:

(1) Absolute safety, both in the boat and supply station, from explosions due to fuel.

(2) Normal radius of action at full speed increased at least 40 per cent.

(3) Maximum radius of action at cruising speed increased over 100 per cent.

(4) Fuel cost per mile reduced about 50 per cent.

(5) The facilities for obtaining fuel in all parts of the world

greatly increased, hence decrease in expenditures for supply facilities.

(6) Slower running machinery, hence probably more durable.

Within the practical limits now set for surface speed a difference of 5 per cent. is negligible, and this will always remain so as long as this speed is measurably less than that of a battleship. These considerations have led to the final abandonment of gasoline engines by all the leading foreign naval powers, viz: Great Britain, Germany, France, Japan and Russia, where kerosene engines are now a "*sine qua non.*" When such engines are available here the United States will doubtless follow suit.

Submerged Motive Power.

For submerged work the storage battery is relied upon as a motive power in all countries. In France a closed-cycle oil engine operating on compressed air has been tried on a large scale in a boat, but has been abandoned, and replaced by a storage battery. This result was about what should have been expected, for the battery has advantages which outweigh those of the compressed-air system. Another type of closed-cycle motor, operating on oxygen, is now under construction, and, if satisfactory results are obtained in shop trials, it will be installed in a boat for trial. From theoretical consideration the latter system has advantages as regards increase of power and submerged cruising radius. It also has an advantage over the battery for boats operating in tropical waters, where it would be difficult to keep the temperature of the battery as low as is desirable. Further advantages of this system are that it dispenses with the main motors and with the necessity for charging batteries. On the other hand, the disadvantages of using any internal-combustion engine for submerged work are: the surplus exhaust gases which may betray the presence of the boat if allowed to escape, or the extra complication involved by the proposed chemical means of taking care of such

gases, the noise and vibration of the engine and difficulty of nice control of power. The distribution of weight of the apparatus is not as convenient as that of the storage battery, but, on account of the increase of submerged power and radius, the system is promising, and may in time replace the battery arrangement.

Torpedo Armament.

As the one weapon of an underwater boat is the torpedo, the question of its selection is a rather important one. The essential qualities of automobile torpedoes are range, speed, war charge and control. For the broad purposes of a discussion of this nature it may be assumed that the latter quality, control, is constant for all makes of torpedoes. That is to say, all good torpedoes will have a small percentage of weight assigned to governing steering and depth mechanisms. As in ship design, wide latitude may be taken in the assignment of weights. Up to the present time the usual practice has been to adopt what may be called a minimum war charge. This varies from 100 to 200 pounds of gun cotton, and has been accepted by various governments with the belief that such an explosive charge is sufficient to do all the damage required. Having satisfied the above-mentioned conditions, there remains a large proportion of the total weight of the torpedo which is devoted to motive power. It depends on the design how this motive power may be used. In certain torpedoes it can be used for a very long range at a moderate speed, or for a moderate range at high speed. In certain other types of torpedo, due to the type of engine employed, there is very little variation in range, although the speed may be varied within wide limits. This peculiarity is merely due to the fact that the engines are not economical at low speeds. It will thus be seen that, even with present designs of torpedoes, there is a considerable variety to choose from, and the choice should be made, giving due consideration to the circumstances under which the torpedo is to be used. For example, if the torpedo is to be carried by a large armored ship, importance should be

attached to the quality of long range. Such a torpedo, when fired against an enemy's fleet, would have an excellent chance of making a hit. The target would then be the fleet and not an individual ship. The probabilities of hitting would be very closely expressed by the product of the length of the ships divided by the length of interval from center to center between ships, or something like 33 per cent. In such a case the individual errors of the gyroscope and errors in estimate of speed of the enemy would not be serious.

As regards the type of torpedo to be assigned to a surface torpedo boat, the lessons taught by the Russia-Japan war indicate that extremely long range is not desirable. It is said that the work done by the torpedo boats toward the close of the war was much better than that at the beginning, for the reason that the torpedo-boat officers had been instructed and had learned from experience that the shorter the range used the better. The reasons for this are apparent. In a torpedo-boat attack the target is more likely to be an individual ship than a fleet of ships. To attempt to hit an individual moving ship at very long range is almost absurd, due primarily to errors in determining the speed and course of the enemy.

Without the aid of any such lessons, however, it is possible, from a consideration of the conditions, to arrive at a conclusion as to the best type of torpedo to be used for a given purpose. When it comes to the question of the arm which we shall supply to underwater torpedo boats, the conclusion unanimously arrived at by those who have given the matter any thought is that the torpedo should have a limited range, say, not more than 1,000 yards, that the speed should be sufficiently high to reduce errors in estimates of speed and course of enemy to such an extent that these errors are small in comparison with the total size of the target and thus to make hits within this range almost certain.

The considerations applying to an underwater boat in action are as follows: Unlike any other type of ship, she is protected by the surrounding medium, the effect of which is to make her invisible for most, if not all the time; or if her presence is

detected she is immune from attack, and the only defense of the enemy is to take refuge in flight, relying upon its higher speed. Under these circumstances the underwater boat can usually select its own range for the firing of torpedoes. When it is considered that the real function of the underwater boat is to sink or disable the other ship, no chances should be taken by long shots. She should get so close that a hit is practically certain, and thus fulfill the object of her creation. This being the case, it is inadvisable to give her a weapon which may be uselessly employed at far greater ranges.

These points having been determined, we have to start out with as a torpedo best suited as an arm for underwater craft, one in which the range is, say, 1,000 yards, and the speed 35 knots. (The above numerical figures are taken more for the purpose of illustration than as an absolute determination. It is quite possible that individual judgment might prefer a slightly greater or less range, or a somewhat greater or less speed.) Accepting these figures, then, as something to work from, it is found that about half the weight now devoted to the most recent types will be sufficient to supply the motive power required. If, then, the torpedo be kept at these original lineal dimensions there remains, after providing for the required range, speed and control, a balance of weight amounting to something like 600 pounds (in an 18-inch torpedo), all of which can be used for purposes of destruction. It can, of course, all be employed in a war charge containing 600 pounds of a high explosive, and such a torpedo would undoubtedly be more valuable for underwater warfare than the present types carrying an explosive charge of only from 100 to 200 pounds. There is no doubt that such an increase in the weight of the explosive charge would produce an increase in the destructive effect. It is much to be regretted, however, that this destructive effect is not anywhere near in proportion to the increase in weight of charge. This fact has been repeatedly demonstrated and undoubtedly has had an important bearing on the decisions of the Admiralties of the world to limit the war charge to the amounts above named.

This question of the relation between weight of charge and destructive effect has such a direct bearing on the matter under discussion that a small amount of space will be devoted to it. The detonation of a high explosive may be defined as a practically instantaneous chemical reaction, in which the large, complicated molecules of the explosive are broken up into simple gaseous compounds, accompanied by an evolution of heat. If we conceive the explosive confined in a vessel which it just fills before the detonation and strong enough to withstand the pressure of the hot gases given off, there will be found a certain maximum pressure in pounds per square inch dependent only on the nature of the explosive and not in any way on the

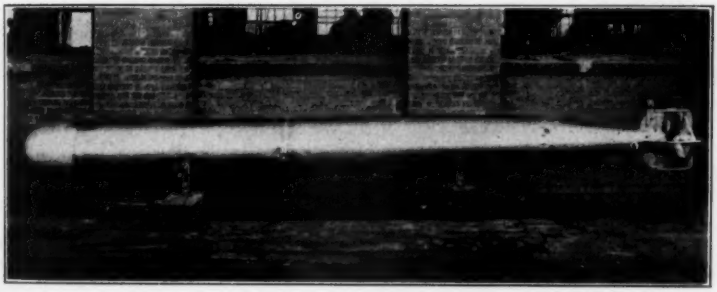


Fig. 26.—WHITEHEAD TORPEDO FITTED WITH 8-INCH DAVIS GUN.

amount of explosive used. Under these circumstances the pressure in pounds per square inch in a vessel of one cubic inch capacity, entirely filled with gun cotton, would be exactly the same as the pressure in pounds per square inch of a vessel of one cubic yard capacity, also originally filled with gun cotton. Thus it is seen that the maximum intensity of the explosion expressed in pounds per square inch does not vary with the amount of explosive used. This intensity is only one of the functions which enter into the determination of the destructive effect. One other very important function is the area of the surface of the structure exposed to the shock. Other variables are the distance and angle from the normal of the center of the explosive charge. An emperical formula, covering these and

checked by innumerable experiments, is given in General Abbott's classical work on Submarine Explosives. If, in this formula, the distance and angle of charge be considered constant, the destructive effect will be found to vary as the two-thirds power of the weight of the explosive charge. On this basis, increasing the weight from 200 to 600 pounds would increase the destructive effect only about 100 per cent. As applied to the torpedo, the distance of the center of the charge does not remain constant, but varies as the cube root of the weight. This fact, taken in connection with General Abbott's formula, would indicate that the destructive effect increases about in proportion to the cube root of the explosive charge. Under these conditions, increasing the weight of charge from 200 to 600 pounds would produce an increase in damage done of only 43 per cent. In view of these considerations it is not surprising, then, that the explosive charge in automobile torpedoes has not been increased at the expense of other features.

But because the weight and space available cannot be used to the best advantage, merely by increasing the war charge, it does not follow that due benefit cannot be obtained from this extra weight available. That is, after having once obtained this extra weight and space, the question arises as to the manner in which to use it to the best advantage. If this is not accomplished by an increase in the weight of explosive carried, it is necessary to look around for other means. Fortunately, other means have already been found, have been tested and proved to be efficient. The new means referred to are embodied in the Davis torpedo gun, illustrated herewith, Figs. 26 to 31, inclusive. For the benefit of those not familiar with this device it may be briefly described as follows: Instead of the usual war head, the torpedo is provided at its forward end with a gun built into or in connection with the air flask. The features of this gun are that the walls, as compared with those of other guns, seem ridiculously thin. As a matter of fact, however, due to the high grade of Vanadium steel employed, the thickness is designed suitable to the purpose intended. This special type of gun is intended to have a life of only one round.

Fig. 27.—Torpedo Shown in Fig. 26, Recovered After Experiment. Gun is Shown Intact Forward of Air Tank.

Therefore, it may be strained to a point just short of destruction. Under these circumstances powder pressures may be employed which compare with those used in the higher-power guns and yet the gun itself may be made very light. Roughly speaking, the weight of the gun is only about the same as that of the projectile, yet such a gun will give the projectile a muzzle velocity of about 1,000 foot seconds, which is in excess of that necessary for any penetration which it is conceivable

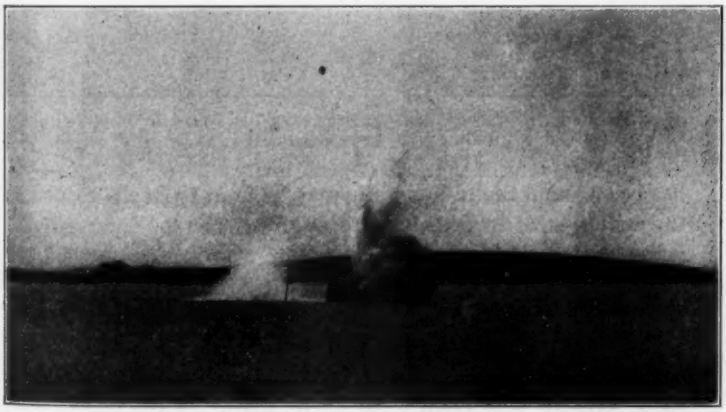


Fig. 28.—Instantaneous Photograph at Time of Explosion. The Cloud to the Right is From the Gases of the Gun, and the Spray to Left Thrown up by the Projectile Traveling 6 Feet Under Water.

would ever be required. The shell itself is also different from the ordinary high-explosive shell in that it contains a very large charge of high explosive. It will never be required to pierce armor, and therefore it does not have to be as strong as an armor-piercing shell. Numerous experiments have been made with this device in an actual torpedo, and all of them have been eminently successful. Several hitherto unnoticed facts have been developed in connection with these experiments. One of these is that of the travel of projectiles under water. The laws of the travel of projectiles in this medium have been roughly determined, and as a by-product of the experiments it

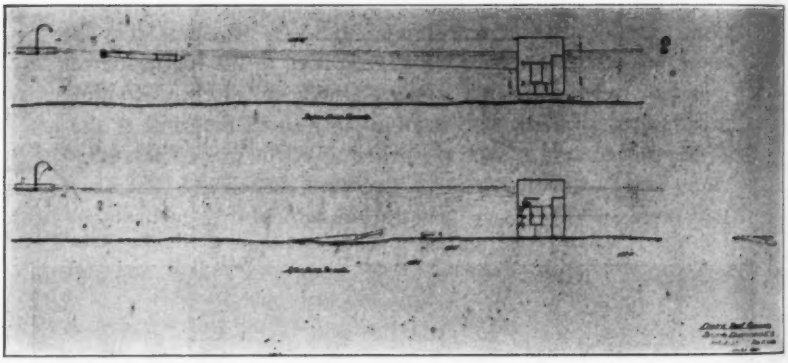


Fig. 29.—Diagrammatic Representation of Torpedo and Target Before and After Experiment.

has been found that a projectile may be fired from the torpedo through a steel torpedo net, through 30 feet of intervening water, after which, on reaching the ship's side sufficient velocity is left to enable the projectile to enter the vitals of any ship now built. The recent discussion of the location of armor belts on battleships is still so fresh in our minds that, without difficulty, we can recall the statement of the leading naval experts, who seem to be all in accord on the disastrous effects which would result from a high-explosive shell entering a ship below the armor belt.

The foregoing statements in regard to this new underwater weapon are not based on theories nor deductions, but on facts determined by actual experiments. In view of these facts it will readily be seen that due advantage may be taken of any increased weight which may be made available for the destructive part of the torpedo. As stated above, 600 pounds may thus be employed. With this weight available, we can use an 8-inch gun, firing a projectile of 250 pounds weight, and containing an explosive charge of about 40 pounds. Only those

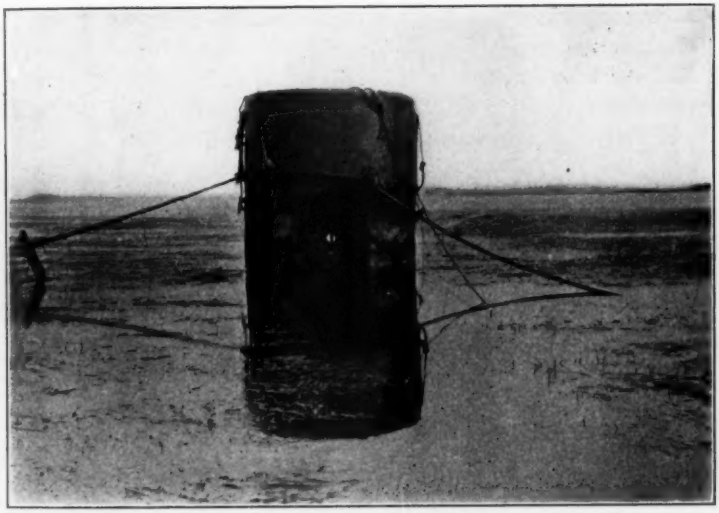


Fig. 30.—PHOTOGRAPH OF TANK AT LOW TIDE, SHOWING DAMAGE TO TARGET AND PATH OF PROJECTILE.

familiar with the effects of the detonation of such a high-explosive shell can fully appreciate the damage which would result when it reaches the interior of a ship from below the armor belt.

To sum up, then, we would have as the torpedo best adapted as an arm of underwater boats, one in which the range is 1,000 yards, the speed 35 knots, and the destructive part, weighing about 600 pounds, consisting of an 8-inch gun, firing a 250-pound projectile with a velocity of 1,000 feet per second.

General.

During the past few years the size of underwater boats has very rapidly increased, some under construction now exceeding 600 tons displacement. This has been partly due to a blind following of the general trend of warship design, exemplified in battleships, cruisers and surface torpedo craft, where increased efficiency of the unit has been gained by enormous

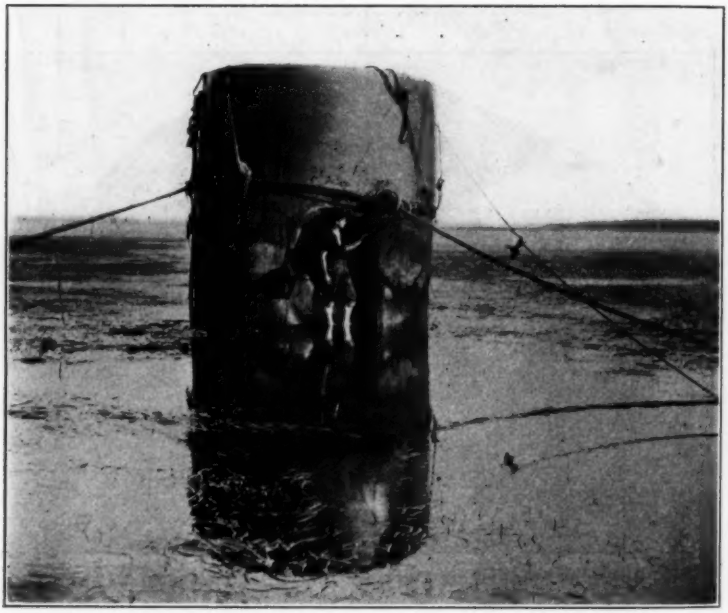


Fig. 31.—PHOTOGRAPH OF TARGET AT LOW TIDE, SHOWING DAMAGE TO TARGET DUE TO GASES OF GUN.

increases in displacement, and partly by a widening of the recognized scope of action of the underwater craft. The latter reason for increased size is sound, the former is not. This arises from the fact that other classes of warships must meet and fight each other, and thus the production of a superior type, for instance, the *Dreadnought,* immediately lessens the

value of preceding and inferior types, possessed by possible enemies. Such is not the case in submarine warfare; the boats do not fight each other, and the appearance of larger and more efficient units does not detract from the existing value of the earlier and smaller ones. Blindly followed, the line of increased displacement will destroy the "*raison d'être*" of the type, which is the ability, at a moderate cost in money and men, to control local sea areas in broad daylight and in the face of a battle fleet. On the other hand, the widening scope of action has required an increase in displacement in order to secure a surface cruising speed and radius sufficient to enable a squadron to accompany a battle fleet when desired. As those qualities, combined with a high submerged efficiency, can be obtained on displacements not exceeding 400 tons, the author believes that at present, taking all things into consideration, greater displacements are a mistake; the game is not worth the candle, and a reaction is due. Certainly such a limitation would increase the controllable sea area for a given expenditure of money and men, both from a tactical and strategical standpoint.

SCHEDULE OF TRIALS AND EXAMINATIONS FOR LAKE AND OCTOPUS.

Paragraph.	*Item.*
C	Speed Trial, Light.
	Speed Trial, Awash.
	Speed Trial, Submerged.
D	Turning Trials, Light.
	Turning Trials, Awash.
	Turning Trials, Submerged.
	Reversing Trials, Light.
	Reversing Trials, Awash.
	Trials Under One Screw, Light.
	Trials at Rest, Submerged.
E	Submerging Trials, Under way.
F	Trials of Behavior in a Seaway.

Paragraph.	*Item.*
G	Torpedo Firing Trials.
H	Trials for Mining and Countermining.
	Handling Torpedoes.
I	Deep Submergence.
J	Determinations Metacentric Height, Light.
	Determinations Metacentric Height, Awash.
K	Endurance Trials, Light.
L	Twenty-four-Hour Submergence.
	Thirty-Mile Run, Light.
	Ten-Mile Run, Partially Trimmed.
	Five Miles Trimmed for Submergence.
M	Trials of Anchor Gear.
	Trial Emergency Sealing Gear.
	Trials Interior and Exterior Communication.
	Trials of Observation Appliances.
	Trials of Pumps.
	Trial of Air Compressor.
	Trials—Facilities for Handling Water Ballast.
	Examination of Steering Apparatus.
	Examinations of Valves and Gear.
	Examinations of Ventilation Appliances.
	Examination of Storage Batteries.
	Examinations of Fuel Supply Storage.
	Examination Machinery, Dismantled After Trials.
	Trials Additional to Schedule.
	Endurance Trials, Submerged.
	Speed Trial Under One Engine.
	Speed Trial, Charging Batteries.

NAVY DEPARTMENT, WASHINGTON, D. C.,
10 o'clock A. M., August 28, 1906.

The Board met pursuant to order.

Present:

Captain Adolph Marix, U. S. Navy, President;
Naval Constructor D. W. Taylor, U. S. Navy, Member;
Commander Burns T. Walling, U. S. Navy, Member;

Lieutenant Commander William S. Smith, U. S. Navy, Member;
Lieutenant John W. Timmons, U. S. Navy, Member; and
Ensign F. H. Sadler, U. S. Navy, Recorder.

The recorder then read aloud the order convening the Board. This order, the order postponing the meeting of the Board to August 28, 1906, and the two orders changing the detail of two officers are appended hereto, marked "A," "B" and "C," respectively.

The Board then agreed upon the following tests and trials:

A. *Time and place of Tests.* That the boats be ready for trial on February 18, 1907, at Narragansett Bay, at which place the trials are to be held.

It is to be regretted that the tests must be completed by March 29, 1907, because the climate in Narragansett Bay in February is very severe, and there is no suitable port farther south.

B. *Nature of Tests.* The tests are to be competitive. In the opinion of the Board it is not practicable to have simultaneous competitive tests for boats of this kind, and a perfectly fair determination of the relative capacities and values can be reached by comparative tests.

C. *Speed Trials.* Speed trials over a measured course of one mile shall be made in three conditions of the vessel, namely: in the "light" or "cruising" condition, with all ballast tanks empty; in the "awash" condition, with the vessel showing not more than half of the conning tower above the water and ready for instant diving; and, third, in the "submerged" condition, with the top of the conning tower not less than ten (10) feet below the surface and the top of the observation mast (hereafter specified), showing at least three (3) feet above the surface.

In the "light" and "awash" conditions speed trials will be made with the engines only, and with the engines connected up with any auxiliary method of propulsion that is provided for in the boat's design. In the "submerged" condition the speed

trials will be made with such method of propulsion as is provided for in the design.

The object of each speed trial is the determination of the maximum speed of which the boat is capable in that condition, and the corresponding revolutions of the screw or screws; also the relation between the revolutions and speed over such a range of speeds below the maximum speed as is likely to be useful in determining actual speeds from recorded revolutions during any trial made in free route. For each speed trial, unless special circumstances render it inexpedient, three runs will be made over the course at the maximum speed, and four or five runs made back and forth at progressively reduced speeds, as determined by the Trial Board; and from the results of these runs the curve of speed and revolutions for the trial will be determined. Additional runs will be made if considered necessary by the Trial Board to obtain accurate results.

D. *Turning Trials. Maneuvering Powers.* The maneuvering powers of each vessel under the three conditions of operation, namely, "light," "awash," and "submerged," will be noted by the Board. Propelling-machinery reversing trials will be made in all three conditions. Twin-screw vessels will be maneuvered under one screw if practicable. The ability of each vessel to maintain steadiness on course in both the horizontal and vertical directions in either the "awash" or "submerged" conditions will be noted during the various trials. Tests will be made to determine the ability of the vessel to remain at rest in any position when submerged. Special further tests may be made by the Board if considered by it necessary or desirable.

E. *Submerging.* The time to pass from the "light" condition to the "awash" condition, and from the latter to the "submerged" condition will be noted; also the time required to pass from one depth to another; also the time required to come to the surface from a depth of thirty (30) feet and to return to that depth. During these trials the changes of the trim of the boat will be observed. The efficiency, safety and convenience

of the methods of submerging will be taken into consideration. The above trials will be made at cruising speed.

F. *Sea Trials.* Advantage will be taken of the weather conditions existing during the time of the trials to determine the vessel's behavior in a sea-way.

G. *Torpedo Firing.* The vessel, carrying her full complement of torpedoes, shall make a submerged run, during which she shall discharge in the shortest time possible all of her torpedoes at a suitable target about 300 feet in length, reloading as may be necessary while completely submerged and under way. Observations of the target shall be taken without coming to the surface except in the case of the last torpedo fired, where conning-tower observations will be taken. The first torpedo will be fired when 2,500 yards from the target.

H. *Mining, Countermining, Etc.* All designs for mining, countermining, cable cutting, and handling torpedoes will be tested, reported upon, and taken into consideration in the final finding of the Board.

I. *Strength and Workmanship.* Each boat, together with all its machinery and appliances, will be examined as to strength, quality of material and workmanship. As a further test of strength each boat will be submerged to a depth not greater than the owners may desire, but no boat will be accepted as fulfilling all the requirements of the Navy Department unless said boat will withstand without damage the stresses due to an actual submergence of at least 200 feet.

J. *Plans and Specifications.* Working plans and specifications of each vessel and all its machinery and appliances must be furnished to the Board. The metacentric heights in the "light" and "awash" conditions will be determined by experiment.

K. *Endurance Trials.* Such runs as the Board may prescribe will be made to determine the radii of action of the vessel under the various conditions.

L. *Habitability.* The habitability of each boat will be determined by the amount of fresh air carried, the amount used during a period of twenty-four hours while submerged, by its

behavior in a sea-way, and by observation of the living spaces in the boat. During the first part of the twenty-four hours' period of submergence the motor will be run for four hours at normal rate of discharge. The living spaces will also be examined after the following runs under gasoline engines alone: thirty miles in the "light" condition; ten miles ready for immediate submergence except for filling main ballast tanks; and five miles with the boat trimmed for immediate submergence; the speed in each case to be the maximum for the condition under consideration.

M. *Inspection.* A thorough examination of each boat and all of its appliances will be made, including efficiency of ground tackle; facilities for sealing the boat in case of emergency; arrangement of steering apparatus and interior and exterior communications; facilities for observation when submerged, both at rest and under way; accessibility and simplicity of valves; ventilation under all conditions; efficiency and protection of storage batteries; condition and efficiency of pumps, both hand and power, and air compressors; facilities for handling water ballast; safety of fuel supply; reliability of all testing and recording instrument, and means of escape in case of necessity.

All testing and recording instruments will be examined and passed on by one or more members of the Board previous to the trial.

After the trial all machinery will be dismantled for examination by the Board.

N. *Condition and Outfit at Trial.* At the beginning of the trial every boat must be presented complete in every respect under service conditions, ready for any service which a submarine boat of its type may be called upon to perform. Each vessel will be fitted with an observation mast, properly secured, of sufficient length to cover the conditions required by paragraph "C" above, and the top of the mast not less than five (5) feet above the top of the appliances used for orientation or observation when submerged.

O. *Recommendation.* It is suggested to the Department that any other trials that any competitor may desire to have his boat

perform be submitted to the Board for its consideration; and that in case any boat is not prepared to perform any one or more of the above tests or trials its failure to do so will be taken into account according to importance.

A. MARIX,
Captain, U. S. Navy, President.
D. W. TAYLOR,
Naval Constructor, U. S. Navy, Member.
B. F. WALLING,
Commander, U. S. Navy, Member.
W. S. SMITH,
Lieutenant Commander, U. S. Navy, Member.
JOHN W. TIMMONS,
Lieutenant, U. S. Navy, Member.
F. H. SADLER,
Ensign, U. S. Navy, Recorder.

ADDITIONAL NOTE.

The method used in the body of the paper for determining possible divisions between surface and submerged speed is, of course, not absolutely accurate, since it is based wholly on weights and takes no account of space, or of the secondary effects upon speeds of the practicable changes in form necessary to secure proper disposition of space. It is impossible, however, to deal with these refinements within the limits of this paper, and in any event the final results would not differ much from those obtained above, provided the same strength for submergence is adhered to.

In conclusion, while some of the aspects of the problem have been subjected to mathematical treatment, nevertheless the whole discussion has been limited to the actual results which it is now certainly possible to achieve in practice, so that the effect upon efficiency of such exaggerations of any one quality as are really feasible may be ascertained. The most important practical conclusion is that at present it is very undesirable to increase the surface speed at the expense of submerged qualities. As noted above, this conclusion might perhaps be debatable if it were possible to increase the surface speed sufficiently to make it materially in excess of battleship speed. Under such conditions the tactics would necessarily be very different and the excess of surface speed over the battleship speed would become very important. Such speed, however, being, for the present at least, out of the question on any displacement within the bounds of reason, detailed discussion of the change in tactics would be futile. That aspect of the matter has been mentioned here for the purpose of pointing out that the value of a knot or two of extra surface speed depends very largely on the starting point. Thus, starting with battleship speed, an excess of surface speed might perhaps be so valuable as to justify sacrifice of submerged speed. Under conditions as they now actually exist, however, where the starting point is of necessity less than battleship speed, it would appear that any feasible increase would not by any means warrant the sacrifice which it would necessarily involve.

ERRATA.

Page 364, Line 8, before word "Lake" insert "Holland and".
Page 366, Table IV, 1st column, after "Average" add "of Ships' forms."

MARINE CONDENSERS* AND SURFACE CONDENSERS FOR STEAM TURBINES.†

The following comprehensive articles on the subject of condensing apparatus have recently been published and will give the reader some idea of the attention condensing apparatus and the securing of high vacuum has received abroad and also the many new and interesting developments that the study, research and experimenting upon this subject is developing.

The subject of condensing apparatus is now one of the most important and interesting in the field of marine engineering, and it is hoped to give in a future number of the JOURNAL a general review of the late developments in condensing apparatus especially as to their application to naval use.

MARINE CONDENSERS.

Mr. Robert Bruce was quite right when he told his audience at the Institute of Marine Engineers on Monday, the 16th of November, that the dependence of the steam turbine on a high vacuum for economy was answerable for various developments which had recently taken place in condensing plant. It is well to remember that for many years marine engineers had been quite satisfied if they got a vacuum within two or even three inches of the barometric vacuum. But Mr. Parsons wants a great deal more than that, and has devised very ingenious, albeit costly, methods of obtaining what he requires. With the reciprocating engine very little is to be gained by working on an exceptional vacuum, the back pressure remaining much the same, for instance, whether the vacuum is 25 inches or 27 inches—not enough, indeed, to compensate for the reduced

* Published in "The Engineer." † Published in "Engineering."

temperature of the feed water. Mr. Bruce considered surface condensation from various points of view, but he left quite untouched one point—namely, the nature of the process of condensation, or, in other words, the phenomena of the transfer of heat from steam to cold metal or cold water. It is quite clear that the actual refrigerating surface presented to exhaust steam by a jet of cold water is insignificant as compared with that of the metal in a surface condenser. Yet the jet is thoroughly efficient; and it is difficult to explain why a foot of tube surface in a cold surface condenser appears to be altogether less efficient than a similar area inside a hot cylinder.

Mr. Bruce laid stress on the necessity for compelling exhaust steam to flow to every part of a condenser, and referred to the use of baffle plates for this purpose. We have never yet heard, however, of any difference existing in the pressures inside a condenser no matter where they were taken; nor is it at all clear that baffle plates have ever been of use. It seems to be of much importance that the tubes shall be kept as dry as possible, and this is no doubt the reason why the Contraflo condenser is so efficient; but precisely why much water hanging on surface condenser tubes should render them inefficient has yet to be satisfactorily explained. The water cannot be hotter than the metal of the tube, and ought in itself to be a perfect cooling medium, but it is not. After all, however, the efficiency of a surface condenser depends on quite another factor. If results are not quite what we desire, then augment the weight of condensing water, or increase the area of the cooling surface, or do both. But given certain settled conditions, a condenser of a given size, air and circulating pumps of fixed proportions, then the number of inches of vacuum will depend far more on the leakage of air into the condenser than on any other factor. We do not think that this truth is appreciated as it ought to be. In the old low-pressure days the engines derived at least half their power from the vaccum, and they were even more dependent than turbines on it. A small crack that could hardly be seen in a jet condenser would render the working of the engines most unsatisfactory and wasteful. Whether a trip was made up to

time or not sometimes depended on the powers of a thick smearing of tallow to keep air out of the condenser. A story is told of an American Monitor, with horizontal engines, which came in for overhaul. When subsequently taken out for trial, a vacuum of about 10 inches only could be obtained. Days and even weeks were spent in trying to ascertain the cause. At last a workman passing over the engines kicked aside a mat on the starting platform which happened to be the top of the jet condenser. The engines were under steam at the time. He heard a whistling noise, and found that a small rivet had dropped out, and air was rushing in. The mat prevented the fact being known. He put in a peg of wood, and the engines at once worked up to their proper speed. If it was possible to keep air out of a condenser, there could be no difficulty in maintaining a very high vacuum indeed. The auxiliaries and devices adapted by Mr. Parsons and others are merely appliances for getting air out. If as much ingenuity was expended in preventing it from getting in, the results would be even better, because prevention is better than cure.

Keeping for the moment to the normal triple-expansion engine, let us see where the air gets in. There ought to be no air in the water, which is boiled over and over again. Nor can any leak into the boilers, except when they are cold. But as there is always a minus pressure in the low-pressure cylinder, air will leak into it wherever it can, and most of all, no doubt, round the piston rod in the stuffing box. The old Cornish engineer quite well understood the importance of keeping air out, and to that end the piston rod was surrounded in the stuffing box with a lantern brass, and this brass was always charged with water, by a pipe and overhead cistern, which effectively kept the air out. A less elaborate device was a large saucer-shaped iron ring forming part of the gland, which, being kept filled with water, prevented air from passing in; but the water was often blown out during the indoor stroke. It is an unfortunate circumstance that leaks of air into an engine do not show themselves. They have to be searched for with the flame of a candle. and that is by no means an easy task. Again, many

condensers leak air, particularly when they are provided with such things as soda cocks and auxiliary feed cocks. Plenty of care is taken that there shall be no steam leaks, but very little attention is paid to air leaks, simply because they are never automatically obvious.

"It is the last straw that breaks the camel's back"—it is the search for the last inch of vacuum that turns the hair of the engineer white. Well may he ask if it is worth the labor spent in getting it. For the reciprocating engine it is not. For the turbine it is absolutely indispensable. Mr. Bruce left nothing unsaid that would direct his hearers in their search for it. When we read about auxiliary condensers, jet air extractors, the entraining of air by water laminæ caused to revolve at a tremendous speed by a small turbine, "augmenters," and other devices named by Mr. Bruce, we begin to think that the modern marine engine room must be a terrible place as compared with its old-fashioned predecessor. No doubt the numbers of marine engineers who will ask what is the advantage gained by the shipowner in pounds, shillings and pence will not be small. Somebody will, no doubt, be a gainer. It would be interesting to learn who he is and how much.—"The Engineer."

SURFACE CONDENSERS FOR STEAM TURBINES.

The April meeting of the Institution of Naval Architects discussed two important communications on condensers and marine turbines.* Mr. D. B. Morison raised the question of the effect of air in surface condensers, and Messrs. C. A. Parsons and J. A. Walker's paper on the "Combination System of Reciprocating Engines and Steam Turbines" concerned cognate problems. Late in June Mr. Thomas C. McBride, of Philadelphia, brought the question of air leakage in steam condensers before the meeting of the American Society of Mechanical Engineers at Detroit.† A few days previous Professor E. Josse, Dr. Ingenieur, director of the Engineering Department of the Technical High School at Charlottenburg, had dealt

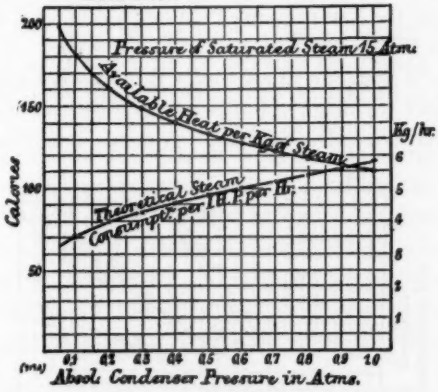
* See "Engineering," vol. lxxxv, pages 502, 511, 532, and 584.
† *Ibid*, vol. lxxxv, page 866.

with the whole problem of "Surface Condensation for Steam Turbines, especially for Ships," in a paper which he read before the Schiffbautechnische Gesellschaft at their summer meeting, held at Berlin on June 16 to 18. Professor Josse has for more than three years been experimenting on the reduction of the dimensions of surface condensers, in conjunction with Dr. Ingenieur Gensecke, and he presented the whole subject to the naval architects, assembled at Berlin, in so comprehensive and lucid a manner that his lecture would deserve attention even if he had not been able to claim novel experiments and success for his aims. The reference to marine turbines is indirect, however. The importance of a further improvement of vacuum is well understood, but the means of realizing the improvement are not clear.

On shipboard, Professor Josse pointed out, surface condensers are always preferred, no matter what type of engine is installed, because the condensed water should at once be fit for return to the boilers. Even in stationary turbine plants preference is often given to surface condensers over the more economical injection condensers, for three reasons: (1) the surface condenser produces a good vacuum more easily than the injection condenser; (2) the condensed water is free from oil, and can at once be re-used; (3) there is a certain danger that the cooling water of the injection condenser might flow back into the turbine. In order to obviate this last-mentioned possibility, Messrs. Franco Tosi, of Legnano, have added a special valve to an injection condenser, which they built for the reserve engine of an hydraulic plant. When the cold water rises above a certain level, a float opens a valve, and the air pressure forces a piston down, which in its descent closes the injection valves. An auxiliary cooler is also provided with the object of securing a good vacuum under the low-pressure piston. In this installation injection condensers had been acquiesced in because economy was imperative. As a rule, however, surface condensers are insisted upon for turbines, and they may cost from 30 to 60 per cent. of the whole turbine plant. On board, moreover, their large dimensions and the weight of metal and water in them are factors of considerable importance.

In his investigation Professor Josse first inquired into the influence of the vacuum on the thermal efficiency of the engine. In the diagram, Fig. 1, the absolute condenser pressures in atmospheres are the abscissæ, and the ordinates are the heat units available at the various condenser pressures with a steam pressure of 15 atmospheres. It will be noticed that the available heat increases considerably as the condenser pressure sinks from 0.3 to 0.05 atmosphere, and that the steam consumption per horsepower hour decreases at an increasing rate when the vacuum is improved. These advantages of a very high condenser vacuum are of much more importance for the turbine than for the reciprocating engine, although this was not generally realized at one time. The reason is that the specific volume

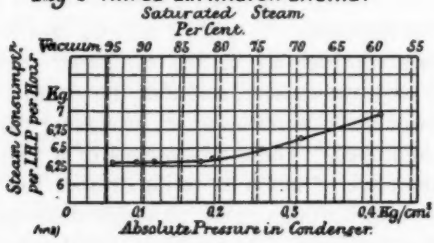
Fig. 1. VACUUM AND THEORETICAL THERMAL EFFICIENCY.



of the steam augments rapidly as the condenser pressure is reduced below 0.2 atmosphere, and that the cylinders of piston engines cannot, for practical reasons, be enlarged to accommodate this volume. The highest condenser vacuum is hence not of much value in reciprocating engines. The diagram, Fig. 2, illustrates some experiments which Professor Josse conducted with a 200-horsepower triple-expansion engine. It will be seen that the improved vacuum resulted in a reduction of the steam consumption until the condenser pressure was diminished to 0.2

atmosphere corresponding to a vacuum of 80 per cent.; the vacuum was further improved to 95 per cent. (0.02 atmosphere), but the steam consumption did not fall any more. The

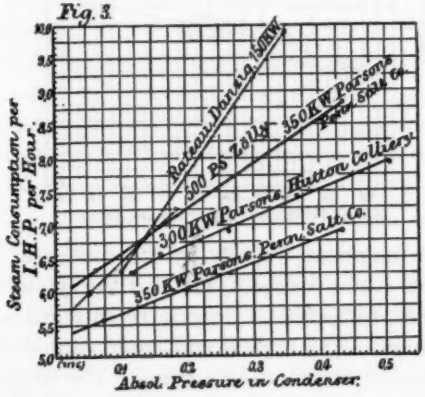
Fig 2 TRIPLE EXPANSION ENGINE.



73 per cent. vacuum of the low-pressure cylinder of the *Deutschland* is only partly utilized for the reason indicated; to avoid making the low-pressure cylinder too large a diameter, a considerable fall of pressure had to be allowed.

The turbine does not labor under this disadvantage. There is ample space for large volumes at the lowest condenser pressures, which are fully utilized. A continued steady diminu-

Fig. 3.



tion of the steam consumption occurs as the vacuum is improved, especially with impulse turbines.

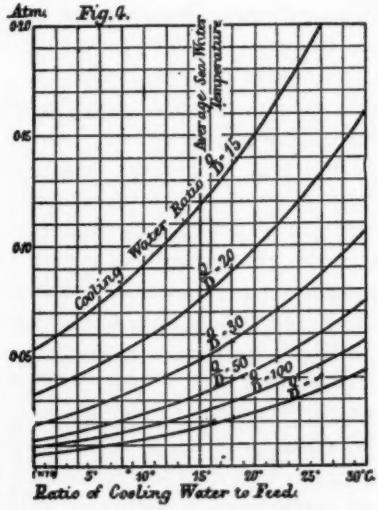
The diagram, Fig. 3, the origin of which is not indicated by Josse, concerns the following turbines: Rateau, Danzig,

150 kilowatts, steam superheated by 45 degrees centigrade (81 degrees Fahrenheit) at 75 per cent. output; 500 horsepower Zoelly turbine, saturated steam, 79 per cent. output; 350 kilowatt Parsons turbine, Pennsylvania Salt Company, steam superheated by 41 degrees centigrade (74 degrees Fahrenheit), 52 per cent. output; 300 kilowatt Parsons turbine, Hutton Colliery, saturated steam, 100 per cent. output; 350-kilowatt Parsons turbine, Pennsylvania Salt Company, 45 degrees centigrade (18 degrees Fahrenheit) superheat, 102 per cent. output. The curves show that the engineer is on the right track when he endeavors further to improve the condenser vacuum. What can be achieved by enlarging the condenser dimensions has already been done, however. It is no good to go further in this direction, and other ways must be found.

The attainable vacuum depends upon the temperature and the mass of the available cold water. Given an unlimited amount of cold water at 15 degrees centigrade (59 degrees Fahrenheit), the steam pressure can be reduced to 0.017 atmosphere, or a vacuum of 98 per cent. be attained. With warmer circulating water, the vacuum will, of course, be poorer, and, with a limited supply of cold water, a rise in the temperature of the cold water has to be allowed for in calculating the possible vacuum. In Fig. 4 specific cooling water curves, ratios of circulating water to feed, are plotted for different temperatures. The ratio is the quotient Q/D, the weight of water Q required per hour—to produce a certain vacuum—by the weight of steam D to be condensed per hour. Taking 15 degrees centigrade (59 degrees Fahrenheit) as the average sea-water temperature, the theoretically realizable vacuum of 98.3 per cent. would drop to 92.5 per cent. when the ratio is reduced to 20—that is to say, when only twenty times as much cold water as steam can be obtained, instead of an unlimited supply of water. On board ship a ratio of 50 or 60 can generally be managed, and an excellent vacuum should hence be realizable, if other considerations did not complicate the problem.

In order that the steam may give off its heat to the cold water, the heat has to pass through the metallic wall of the con-

denser, and in this process heat is taken up at three stages; in the transference from the steam to the metal, in the metallic wall of thickness δ and thermal conductivity λ, and in the transference from metal to the water. The coefficient of transference, κ the number of calories transferred per hour through 1 square meter of metallic condenser wall, when the temperature of the steam is 1 degree centigrade higher than that of the water, can be deduced from the formula $\frac{1}{\kappa} = \frac{1}{a_1} + \frac{\delta}{\lambda} + \frac{1}{a_2}$. The best known of these three terms is the middle term. The number of calories passing through a wall of 1 millimeter in thick-



ness (which is approximately the thickness of a condenser wall) per square meter of area at a temperature difference of 1 degree centigrade is for brass about 90,000, for copper 300,000, for iron 55,000, for zinc 28,000, for tin 54,000, and for aluminum 13,000. The term δ/λ would hence have the value of 1/90,000; and it will be seen that this term is relatively unimportant for this consideration. The a_2, or rather the transference from water to metal, has been investigated with the aid of two concentric tubes, water being sent both through the

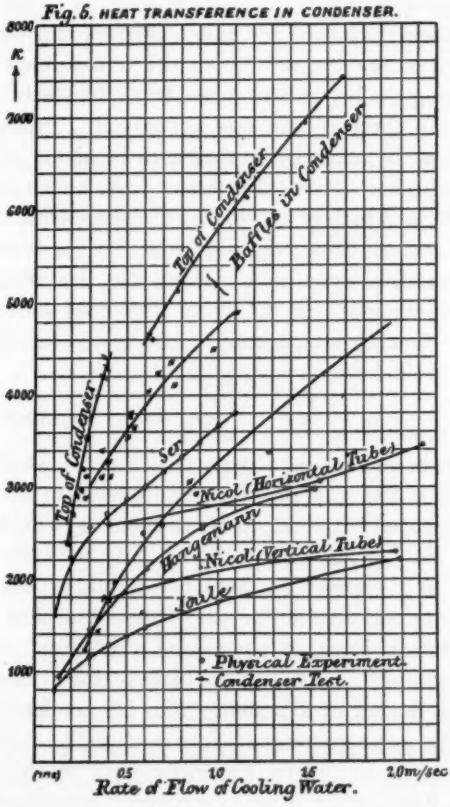
inner tube and the annular jacket. The values of various experimenters are little in accord, however. Professor Josse agrees best with Ser, who gave the approximate formula $a_2 = 4{,}500\sqrt{v}$, where v is the velocity of the water through the tubes.

This velocity is the decisive factor—as will be presently shown—far more important than the material of the condenser walls and their thickness, and also of greater consequence than the velocity of the steam. About the transference coefficient a_1 concerning the heat transference from the steam to the condenser metal, there is still less agreement. Professor Josse states that a_1 is generally supposed to be about 10,000. Ser assumed a higher figure. Professor Josse concludes from an analysis of Ser's figures and his own experiments, that 19,000 is a more correct value; the heat transference from steam to metal is certainly very high. Here also the velocity of the steam is of influence; but the whole term does not count much. For water flowing at the rate of 0.5 meter (20 inches) per second, Josse's formula would be

$$\frac{1}{\kappa} = \frac{1}{19{,}000} + \frac{1}{90{,}000} + \frac{1}{3{,}180}, \text{ and } \kappa \text{ therefore } 2{,}640.$$

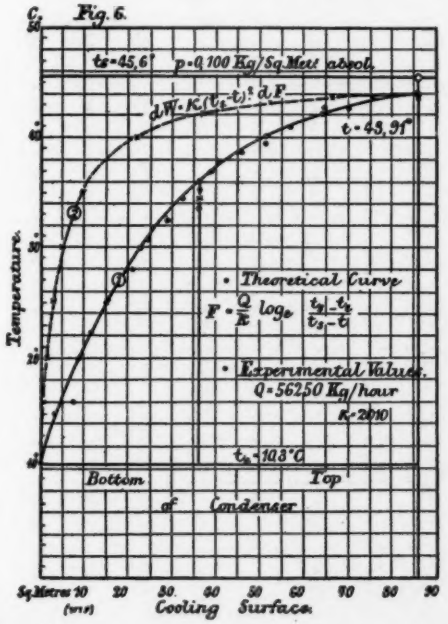
If the a_1 be increased to twice its value, κ would only rise 2,840; and if the wall thickness be doubled to 2 millimeters, when the second term would be doubled, κ would hardly be affected. But an increase in the rate of the water flow from 0.5 meter to 1.5 meter (5 feet) per second would raise κ to 4,530. As an increase in the rate of the steam flow is undesirable, Professor Josse advocates the quickening of the cold-water circulation. By fixing the baffle strips of Messrs. Pape, Henneberg & Co., of Hamburg, into his condenser, in order to break the water currents up into vortices, he raised the κ at a water velocity of 1 meter (40 inches) per second from 3,000 to 4,500. The results of his experiments, conducted with condensers, and of experiments made by others with physical apparatus, are plotted in Fig. 5; the curves show that in condenser tests better results are obtained than in experiments conducted in the physical laboratory, and they also bring the beneficial influence of the baffles out strongly.

The coefficients κ, marked in Fig. 5, as above explained, to the heat transference in calories per hour from the steam to the cooling water through 1 square meter of metal at a temperature difference of 1 degree centigrade. Opinions again differed concerning the increase in κ with greater differences of tem-



perature; according to some, the heat transferred should increase proportional to the difference; according to others (Weiss), proportional to the square of the temperature difference. Josse investigated this question by placing thermocouples in different portions of the condenser tubes. If the heat

transferred increased as a linear function of the difference, then the rise of temperature in the cold water should follow an exponential law; this was found to be so, Professor Josse's theoretical and experimental curves being in perfect agreement (see Fig. 6). His formula is $F = \frac{Q}{K} \cdot \log_e \frac{t_s - t_e}{t_s - t}$, where t_s is the saturation temperature, and t_e the temperature of the cooling water at entrance; it will be seen that the quadratic formula of Weiss does not at all conform to the theoretical curve.



Before Professor Josse could proceed to a calculation of the suitable condenser dimensions, however, the influence of air leakage had to be studied. Together with the exhaust steam, air passes into the condenser. The temperature of the air will be that of the steam, and the pressure of the mixture will, according to Dalton's law, be the sum of the partial steam pressure and of the partial air pressure. The air pump has to with-

Heat Transference Coefficient for Air.

Length of pipe, 1,320 millimeters (52 inches); internal diameter, 23 millimeters (0.91 inch). Air-flushed surface, 0.0954 square meter = 148 square inches.

No. of experiment.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.
Air pressure, absolute, atmosph'rs.	1.034	1.034	1.034	1.034	1.034	1.034	1.034	0.515	0.515	0.512	0.510	0.515	0.106	0.104	0.106	0.106	0.106
Steam temperature, degrees C.	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Air temperature, entrance, deg. C.	16.7	16.9	18.4	19.7	20.3	21.1	19.7	19.7	19.5	19.6	20.0	20.0	26.9	30.2	30.5	32.5	36.5
Air temperature, disch'rge, deg. C.	58.8	62.5	69.0	71.5	73.5	71.6	77.3	65.3	74.0	75.5	79.2	83.9	72.0	84.3	84.4	87.1	84.5
Air temperature, mean, deg. C.	38.0	40.0	44.0	46.0	47.0	46.0	48.5	42.5	47.0	47.5	49.5	52.0	50.0	57.0	58.0	60.0	61.0
Air weight per hour, kilograms.	32.2	20.95	11.08	7.59	5.86	4.16	2.46	15.54	8.89	6.95	3.95	2.19	1.726	1.250	0.812	0.665	0.239
Air volume per hour, m^3.	28.3	18.6	9.93	6.86	5.3	3.76	2.24	27.9	16.20	12.75	7.31	4.04	15.38	11.6	7.42	6.09	2.2
Air speed in pipe, m. sec.	18.96	12.46	6.65	4.6	3.55	2.52	1.5	18.7	10.85	8.54	4.89	2.71	10.3	7.77	4.97	4.08	1.47
Calories transfer'd per hour.	323.0	228.0	133.4	93.5	74.2	50.0	33.7	168.6	115.5	92.3	55.7	33.2	18.5	16.11	10.4	8.65	2.73
Heat transference coefficient, κ.	56.3	41.8	26.9	19.6	16.1	10.6	7.78	32.6	25.2	20.6	13.3	8.73	4.13	4.66	3.03	2.76	0.84

draw the air. If the withdrawal took place at the temperature corresponding to the condenser pressure, the partial steam pressure would become equal to the condenser pressure—that is to say, the partial air pressure would be zero, and the pump would have to deal with an enormous air volume. The air pressure should therefore not be reduced to zero, and the temperature be lowered at the spot where the air is withdrawn, below the saturation temperature of the condenser pressure. The condenser has hence to cool the air as well as the steam, and this is not easily attained. For, while the heat transference from steam to metal takes place readily, the respective coefficient κ being, in a round number, 20,000, air is known as a good thermal insulator, and its κ is of the order of 10. Experiments on the heating of air when passing along pipes had been made by Ser. Ser noticed that the κ improved with the diameter of the pipes and also with the velocity of the air; his pipe diameters ranged from 10 millimeters up to 50 millimeters (2 inches); but he did not introduce a diameter term into his empirical formula, and all his experiments were conducted at ordinary air pressure. In the condenser vacuum the heat transference should obviously be smaller than at atmospheric pressure, and Josse investigated this problem by passing air, at different speeds and pressures, through a pipe 23 millimeters (nearly 1 inch) internal diameter, 1,320 millimeters (52 inches) in length, placed in a steam bath at 100 degrees centigrade. The diagram, Fig. 7, explains the arrangement. The air was drawn by a pump through a meter, its volume determined, and its pressure adjusted by means of a valve inserted between the meter and the pipe. The heat transference from the steam through the pipe wall to the air was deduced from the heating of the air and checked by determining the amount of condensation taking place in the steam jacket. The table above reproduces the results of these experiments, which are elucidated by the diagrams, Figs. 8 and 9. While the κ is about 10 at air speeds of a few meters per second, when the air is under atmospheric pressure, the κ is diminished to 3 at a speed of 5 meters (16½ feet) when the air pressure is reduced to 0.11 atmosphere. The figures are striking.

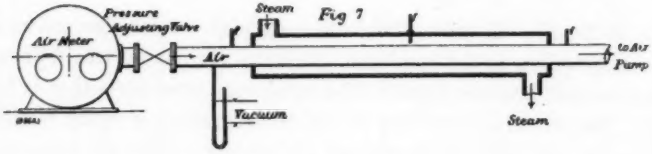


Fig 7
Pressure Adjusting Valve
Steam
Air Meter
Air
to Air Pump
Vacuum
Steam

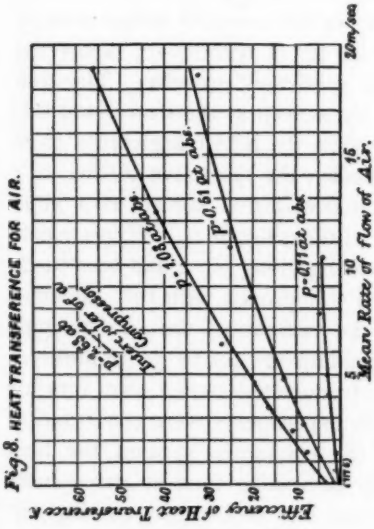


Fig 8. HEAT TRANSFERENCE FOR AIR.
Efficiency of Heat Transference k
Mean Rate of Flow of Air.
p=0.11 at abs.
p=0.61 at abs.
p=1.03 at abs.
Baker's plan of a Condenser.

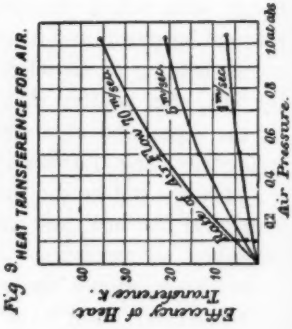


Fig 9 HEAT TRANSFERENCE FOR AIR.
Efficiency of Heat Transference k.
Air Pressure.

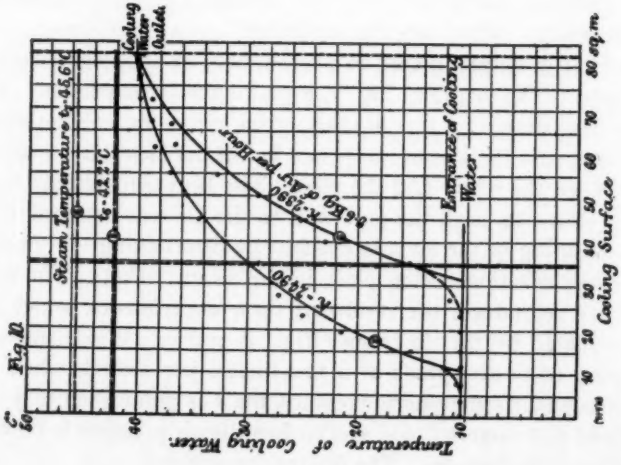


Fig 10
Steam Temperature t=45.6°C
Cooling Water Outlet
Entrance of Cooling Water
K=1990
K=1430
Temperature of Cooling Water.
Cooling Surface

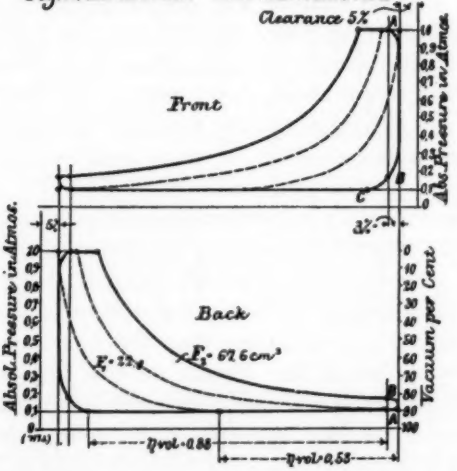
The experiments indicate that the rate of flow of the water, which is decisive for the cooling of the steam, will be of little consequence for the cooling of the air, which will essentially depend upon the rate of flow of the air. As a brisk air circulation in the condenser cannot be permitted, large cooling surfaces have to be provided. The curves of Fig. 10 illustrate the rise in the temperature of the cooling water resulting when different amounts of air enter the condenser. These temperatures are the ordinates; the abscissae are the cooling surfaces (or pipe lengths). Curve 5 concerns a case in which the exhaust did not contain much air, curve 6 a case in which it contained a good deal of air, 9.6 kilograms of air being allowed to leak in per hour. In both cases the first portion of the curve is horizontal—*i.e.*, there was no temperature rise at first, and in curve 6 about 40 per cent. of the total condenser surface seems to have essentially served for cooling the air. If the exhaust were free of air, the curve would at once rise; one of Josse's curves shows this quite clearly.

In steam turbines it is, fortunately, more easy to keep the air out than in reciprocating engines. In the turbine the air can only gain access, as a rule, through the shaft glands which are packed with water, oil or steam; the amount of steam wasted by the packing is less serious than the deterioration of the vacuum by air would be. Steam turbines are, however, as liable as reciprocating engines to air contamination through the feed water, if the pipes are leaky or the pumps do not work well. Yet with well-constructed turbine sets the amount of air delivered with the exhaust should be very small. Josse's experiments with the 300-kilowatt Parsons turbine of the Charlottenburg High School show that not more than 0.25 kilogram of air was delivered per hour when 3,000 kilograms of steam were consumed per hour.

Passing to the condenser pumps, Professor Josse points out that the air and the condensed water may either be removed separately, the air by a so-called dry-air pump, or, both together, by a wet-air pump. The dry-air pumps have, at high vacua, to deal with high-compression ratios; in a vacuum of

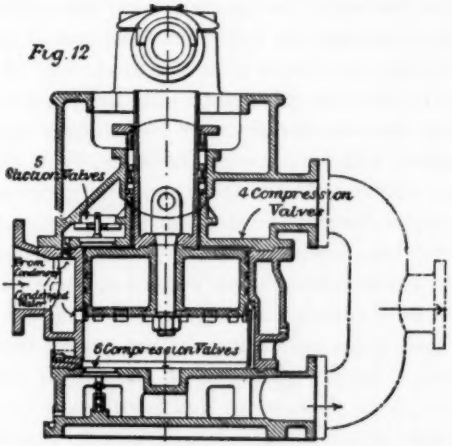
90 per cent. the ratio is 1 : 0.1 = 10; in a vacuum of 95 per cent. the ratio is 20; and if the air is compressed and withdrawn in one operation the clearance must be small. When the clearance amounts to 5 per cent. the vacuum cannot be maintained at more than 95 per cent., since the pumps would not suck up any air. The clearance must, therefore, be reduced, or other expedients be adopted. Three are mentioned. Firstly, the air-pump compression may be effected in two stages; such pumps for steam turbines are built by the Allgemeine Elektricitäts-Gesellschaft. Secondly, the pump is fitted

Fig. 11. DRY AIR PUMP WITH BALANCING PIPE



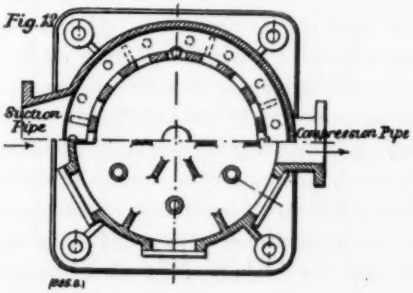
with an equalizing pipe, ports being provided such that the two piston sides are interconnected near the end of each stroke. The indicator diagrams of Fig. 11 illustrate the performance of such a pump, which is working with a clearance of 5 per cent. on a condenser with a vacuum of 90 per cent. At the point A the piston front, under atmospheric pressure 1, is connected with the back, where the pressure is 0.1; the pressures will be equalized to 0.168 atmosphere. At point B the balancing pipe is closed. The air in front of the piston will expand back down to condenser pressure C, while in the rear the air

will be compressed. The volumetric efficiency is by this expedient raised from 0.53 to 0.88, but considerably more power—63 per cent.—is absorbed to accomplish this. The reason of



this increase in power is that a considerable portion of the already compressed air expands back without doing useful work, and has to be recompressed.

The third expedient concerns the wet-air pump. The clearance space is made to receive the condensed water, which will

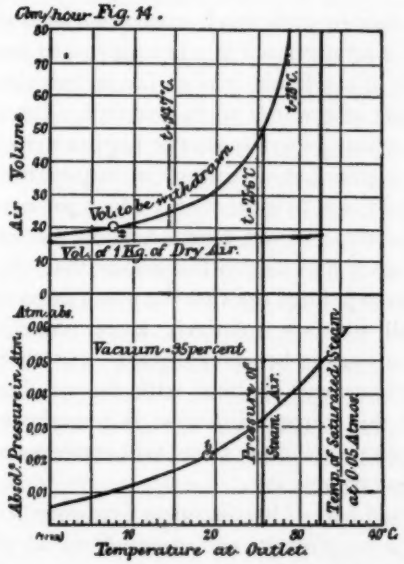


fill at least part of it. Figs. 12 and 13 illustrate the construction of Professor Josse's double-acting wet-air pumps. The condenser sends its mixture of water and air to a jacket sur-

rounding the vertical pump barrel. About halfway up this barrel is provided with a series of slots, communicating directly with the jacket. The slots are covered during the down stroke and cleared at the end of the up stroke, and the condensed water can only pass through the slots into the lower portion of the cylinder. When the piston is at the upper end of its stroke some air will simultaneously escape into the cylinder. As soon as the piston descends the slots are closed, and water and air are compressed and forced out, the water first, through the compression valves. At the same time air is drawn into the upper portion of the cylinder through the suction valves; these latter valves close when the stroke is reversed, and the air-compression valves open; the air suction is, therefore, continuous. In order to ensure that the piston always runs in the wet several by-pass ports connecting the two piston faces are provided in the cylinder. Just before the piston comes to its lower stop it clears these ports, and a little water is forced up on to the upper piston surface; this water also absorbs the heat produced by the air compression. A photograph shown by Professor Josse referred to a pump of his design: cylinder diameter, 500 milimeters (20 inches); stroke, 160 millimeters (6.3 inches), running at 250 revolutions for a plant condensing 10,000 kilograms of steam per hour, with a vacuum of 93 per cent. The suction resistance of these pumps must be reduced to a minimum, and this is secured by the aid of slots and of valves of the weight of a few grams.

We return to the temperature at which the mixture of condensed water and air should be withdrawn. The case represented in Fig. 14 is that of a 95 per cent. vacuum; 1 kilogram of air enters per hour, and the air-pump capacity is 50 cubic meters (1,765 cubic feet) per hour. The abscissae are the temperatures at the condenser outlet. If the pump had merely to remove dry air, the volume of air would be little influenced by the temperature, as the straight line (volume of 1 kilogram of dry air) in the upper part of the diagram indicates; at 0 degrees centigrade 16 cubic meters would have to be sucked up, at saturation temperature (32.5 degrees centigrade) 18

cubic meters. But the partial pressure of the air at saturation temperature dwindles to zero (curve 1), and the air volume becomes very great (curve 2). In the case represented the volume to be removed would already equal the pump capacity of 50 cubic meters at 25.6 degrees centigrade, when the partial air pressure will be 0.017 atmosphere. If the pump had a capacity 80 cubic meters (2,800 cubic feet) per hour, then the temperature might rise to 29 degrees centigrade; if, on the other hand, 2 kilograms of air should leak into the condenser



instead of 1 kilogram, the cooling should be carried down to 15 degrees centigrade.

In a certain measure the temperature of the discharged air is a criterion of the fitness of the condenser plant. But caution must be exercised in forming an opinion. The claim that the condenser must work the better, the lower the temperature of the discharged air, is unjustified; the air temperature may be low, because there is much air leakage, or because the pump delivery is poor. Professor Josse explained these features by further

diagrams. Air leakage into the condenser becomes a serious factor when a high vacuum is to be utilized. The air must be cooled, whether a dry or a wet-air pump be used. As regards the temperature of the condensed water, the two systems differ. When the air is separately withdrawn, the condensed water need not be cooled. When a wet pump is used, however, extra cooling of the condensed mixture is necessary, lest an after-escape of air ensue. This extra cooling is effected in various ways. Professor Josse first cools the liquid and then the air by bringing it into intimate contact with the liquid; as the cooling of water requires much smaller surfaces than the cooling of air, this arrangement is said to save surface space. The extra cooling of the liquid is in so far undesirable, as the cold feed water has afterwards to be reheated. But with modern high vacua, which generally do not require a cooling of more than a few degrees below saturation temperature, this loss of heat will not amount to more than 1 or 1.5 per cent. of the heat of the feed water, and wet pumps are, on the whole, simpler, occupy less space and absorb less power than dry pumps. It has already been pointed out that the pump fitted with a balancing pipe will consume relatively more power, because the re-expanded air has to be recompressed. Another point is that the steam withdrawn, together with the air, has to be compressed; for this purpose injection is sometimes resorted to. In the wet pump this latter steam will condense again as soon as compression commences.

In the second part of his discourse Professor Josse gave particulars of the experiments and observations on which his conclusions were based. These observations have extended over three years, during which his improved condensers have continued to work satisfactorily.

The first series of tests concerns the 300-kilowatt Parsons turbine of the Engineering Laboratory, which a vertical pipe of ample dimensions connects with the cylindrical surface condenser below; the wet-air pump of Josse is driven by belting from an electric motor at 300 revolutions. The chief dimensions of the condenser are as follows:

Cooling surface	89 sq. m. (958 sq. ft.)
Tubes, internal diameter	18 mm. (0.71 in.)
Tubes, external diameter	20 mm. (0.79 in.)
Tubes, length	2,300 mm. (90.5 in.)
Number of tubes, upper set	346
Number of tubes, lower set	342
Number of tubes, total	688
Water-washed surface, upper set	44.9 sq. m. (483.5 sq. ft.)
Water-washed surface, lower set	44.4 sq. m. (477.9 sq. ft.)
Water-washed surface, total	89.3 sq. m. (961.0 sq. ft.)
Total cross section of tubes, upper	0.0879 sq. m. (136 sq. in.)
Total cross section of tubes, lower	0.0868 sq. m. (135 sq. in.)

We do not reproduce the two tables of experimental data. Several groups of tests may be distinguished. In the first group the load on the turbine was kept normal, and the amount of cooling water was varied between the ratio values 40 and 17. In the second group the load and steam consumption were varied; in some cases the temperature of the cooling water was artificially raised from about 10 degrees to 20 degrees centigrade (50 degrees to 68 degrees Fahrenheit). In a third group the general conditions were the same as in the second, but the highest realizable vacua were determined (97.9 per cent. was the maximum). The fourth group concerned the influence of air leakage. The heat quantities sent into the condenser were determined in two ways from the amount and temperature of the steam, and from the temperature rise in the circulating water; the two determinations agreed in all cases (but one) within 1 per cent. In some cases the steam was superheated. The average duty of the condenser was 35 kilograms of condensed steam per hour per square meter (7 pounds per square foot) of cooling surface. When the volume of cooling water has to be kept low the suitability of the disposition may be judged from the excess of the actually used water over the theoretically necessary amount of water. This excess amounted at the highest vacuum to 16 per cent., and went down to 5 per cent. with a vacuum of 90 per cent. The difference of temperature between the saturated condenser steam and the discharged cooling water was generally less than 2 degrees centigrade.

The average coefficient of heat transference was high, above 3,000, and even 4,000, although the rate of flow of the cold water was, as a rule, only 0.4 meter (16 inches) per second. This high efficiency is ascribed to the good services of the baffles; in some special tests the just-mentioned difference in the temperature of steam and discharged cooling water amounted to about 3 degrees centigrade when baffles were used, and to 9 degrees when they were not used. As the cooling water used is very pure, the baffles had not required any cleaning in three years. When air was allowed to gain access the heat transference coefficient was considerably decreased, *e.g.*, to one-half its value, when 13.5 cubic meters (475 cubic feet) instead of 0.20 cubic meter (7 cubic feet) of air were admitted per hour. The condensed-water pump absorbed only 0.5 per cent. of the turbine power. This power may, however, rise to four times that amount on starting the pump; the electric motor must hence be able to take a heavy overload.

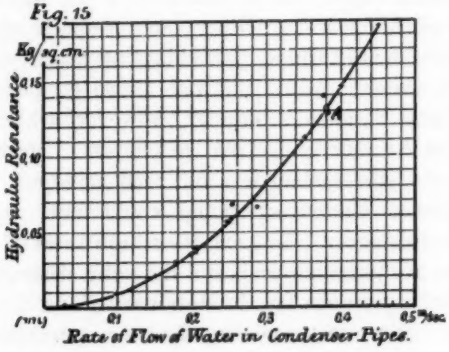
The second condenser experimented with was that of the 200-kilowatt turbine of the laboratory, supplied by the Allgemeine Elektricitäts-Gesellschaft. This condenser was built for experimental purposes and is of peculiar construction. It consists of 620 tubes, disposed in an upper and a lower condenser; 189 of the tubes of the upper condenser run crossways, their length being 588 millimeters; the three sets of longitudinal tubes have each a length of 1,200 millimeters, the common internal diameter is 15 millimeters, and the total cooling surface 28.52 square meters. This small area is to condense 2,000 kilograms of steam per hour, 65 kilograms per hour per square meter (13.3 pounds per square foot)—nearly twice as much as the first condenser. The best vacuum reached was 96.4 per cent., and nearly 50 per cent. more than the theoretical amount of cooling water was needed for this performance; the wet pump was also too small. The heat transference was very good; the coefficient rose to 7,200 in the case of the top tubes; for the condenser as a whole the heat transference was 3,840, when the cooling water ratio was 50. The cross tubes were added to see whether vortices set up in the steam would raise the efficiency; no such effect could be observed.

Professor Josse further discusses tests of some other condenser installations. In one instance a vacuum of 97 per cent. was realized by a firm of steam-turbine constructors; but the engine did not work economically, as the amount of cooling water required was by several hundred per cent. higher than the theoretical figure. The ratios were 98, 169 and 596 at vacua of 96.4, 97 and 97.6 per cent., respectively. In tests of a marine steam turbine, particulars of which tests are also given, the vacuum would not rise above 82 per cent. The cooling water ratio was only 21, however, while 50 would, perhaps, be the average for marine engines. Here the reason was that the pipe system was not well arranged, so that the 70-horsepower circulating pump could not overcome the hydraulic resistances. In such cases high rates of flow in the cold water are uneconomical, and the point deserves attention. The circulating pumps are, in stationary plant, as a rule, centrifugal electric pumps, whose efficiency decreases rapidly as soon as they have to overcome a greater resistance than they are designed for. On board directly-coupled steam engines are more frequently used, but even in their case the duty should not be underrated.

The hydraulic resistance which a pipe system opposes to the flow of water is proportional to the length of pipe and to the square of the velocity of the water. If ξ is the constant, then $R = \xi v^2$. Professor Josse tested this formula on the condenser of the 300-kilowatt turbine and found that it applied strictly for the range tried, rates of flow up to 0.5-meter second. The full dots again indicate experimental results, the circles theoretical points on the curve of Fig. 15.

Of his other remarks we will only mention one more. He questions the justification of the general distinction between contra-flow and ordinary flow. For the greater portion of the condenser there is a rise of temperature only on the water side; the temperature on the steam side remains that of the saturated steam, and the term "contra-flow" should, strictly speaking, only be applied if there is a temperature fall in the one direction and a corresponding temperature rise in the opposite direc-

tion. So far as the condensation is concerned, it is pretty immaterial in which direction the water flows. The contra-flow principle is, however, correct and necessary for the smaller portion of the condenser in which the condensed liquid is to be cooled together with the air; for the air must be withdrawn



from the coldest spot. But it seems inadvisable, in Professor Josse's opinion, to attempt to direct the flow of the steam on the contra-flow principle, as that would obstruct the steam flow and create a pressure difference between different portions of the condenser, which would be injurious to the maintenance of high vacua.—"Engineering."

SUBMARINE SIGNALING.

The following has been submitted by the Submarine Signal Company and the subject is of particular interest to the seafaring world.

A ship at sea may be lost:

1. By an accident in the ship itself (a fire or a break in machinery).
2. By foundering or being driven ashore by storm, or
3. By running into something without warning—
   a. the coast,
   b. another ship,
   c. icebergs,
   d. derelicts.

The dangers from (1) and (2) to a great extent have been eliminated by naval engineering. The dangers from (3) are entirely due to lack of warning. In clear weather, in daylight, they are readily avoided. At night, so far as the coast and other ships go, the use of lights has made it as safe to navigate as in the day time. The proximity of icebergs is known by the chill in the air and by the temperature of the water. Derelicts are now systematically reported and when possible destroyed. As neither icebergs nor derelicts are under human control, it is impossible ever entirely to do away with the dangers they create, but these are relatively insignificant. The chief danger at sea today is due to the fact that in thick weather a vessel does not receive an accurate and reliable warning of an approaching ship or of a dangerous point on the coast.

In order to get such a warning we must use either light, sound or electricity (at present we know of no other means for signaling) and the signal must be transmitted through the air or through the water. The air is an unreliable medium, for

it is not uniform. In clear weather a light is admirable, for it not only warns a vessel of danger, but tells the direction in which it lies. The most powerful lights, however, cannot penetrate fog, smoke or snow storms. Sound is so deflected and refracted by the varying density of the air that when heard it does not indicate the direction from which it comes, and often skips over spaces near by and cannot be heard at all. Electrical storms and disturbances constantly vary the conditions under which wireless telegraphy and telephony operate. In short, the air is a variable and inaccurate medium for signaling.

The water, on the other hand, is uniform in density and transmits sound uniformly in every direction. It is a bad medium for light, and so far as experiments have gone, electricity cannot be transmitted under water except for a short distance.

It is apparent that the use of sound under water is the only means that in thick weather will do what a light does in clear weather; *i.e.*, give warning of the danger and *where* it is. The real problem is the mechanical one of producing efficient sending and receiving devices for submarine signaling. Not only does it give warning, but it acts as a guiding beacon. By its use a fishing schooner can find its dories, an ocean liner can pick up its tender, or find its way into a harbor, or locate its pier. After days of dead reckoning it tells a captain where he is and furnishes a mark from which he can lay his course.

Moreover, in time of war, by means of submarine signals, it would be possible to do away with lights altogether, and by moving the bells to points unknown to the enemy make navigation on the coast too dangerous for them to attempt at night. The home fleet, on the other hand, could leave the harbor and return in perfect safety, being guided only by the bells.

PRESENT DEVELOPMENT.

The danger of running on the coast in thick weather has been eliminated where bells protect the dangerous points and the ships have the receiving apparatus. The navigating officer

hears the warning and locates it exactly in ample time to avoid danger.

There are three kinds of bells:

1. To be used on light ships and rung by compressed air;

2. To be hung from a tripod on the bottom of the sea and rung by electricity through a cable from the shore;

3. To be attached to a buoy and rung by the motion of the waves.

On the Atlantic Coast bells are installed on the following lightships: Cape Elizabeth, Me., Boston, Mass., Pollock Rip Shoals, Mass., Pollock Rip, Mass., Great Round Shoal, Mass., Nantucket Shoals, Mass., Hedge Fence, Mass., Hen and Chickens, Mass., Vineyard Sound, Mass., Brenton Reef, R. I., Cornfield Point, Conn., Fire Island, N. Y., Ambrose Channel, N. Y., Northeast End, N. J., Five Fathom Bank, N. J., Overfalls, Del., Fenwick Island Shoal, Md., Winter Quarter Shoal, Va., Cape Charles, Va., Tail of the Horseshoe, Va., 35-Foot Channel, Va., Diamond Shoal, N. C., Cape Lookout Shoals, N. C., Frying Pan Shoal, N. C., Brunswick Bar, Ga., South Pass, La., Heald Bank, Tex.

The Government is being urged to also instal bells at the following danger points on the Atlantic Coast: Deer Island, Martinicus, Camden Ledges, Monhegan Island, Seguin Ledges, Thatchers Island, The Graves, Peaked Hill Bar, Nauset, Handkerchief, Cross Rip, Shovelful, Gay Head, Point Judith, S. W. Ledge, Block Island, Little Gull Island, Middle Ground, Stratford Shoal, Execution Rock, Barnegat, McCree Shoal, Del. Bay, Cape Romain, Little River, St. John's River, Jupiter Inlet, Fowey Rocks, Carysfort, Alligator, Sombrero, American Shoal, Sand Key, Tortugas, Mobile Bay, Sabine Pass, Heald Bar.

This is a matter of the greatest importance to shipping interests, and further delay on the part of the Government would hardly seem justified, particularly as the apparatus necessary for these installations can be obtained practically at the cost of manufacture.

In using a bell for signaling between ships obvious difficul-

ties present themselves. A bell slung overboard from a moving ship is not practical, and when placed in a tank inside the ship, it loses its carrying power by the dampening effect of the ship's sides. Experiments show that the range of a bell so placed is greatly reduced, and although of service to slow ships it does not send its sound far enough to give fast ships sufficient time to maneuver. What is needed is a more powerful sounder which will send the sound out through the side of the ship from a tank in the forepeak to a great distance. This is being perfected, and when it is, the most timid passenger can go to sea without apprehension.

In the case of submarine boats, however, owing to the fact that the bell is hung in the perforated superstructure, and its sound is transmitted directly to the open sea, it is entirely practical to signal from one to the other. The enormous value of this is at once apparent when it is realized that when submerged these boats have no other means of communicating with the surface. By the use of codes, submarine boats can remain in constant communication with the flagship equipped with a lightship bell and with each other. It enables them to maneuver in flotillas and to make a converging attack under water on a battleship, something entirely impracticable and far too dangerous to attempt without submarine signals.

A submarine boat sunk by an accident could be located by its signals, and what would otherwise be the certain loss of all the crew might be avoided.

The receiving apparatus may be called the "ears" of the ship. On the inside of the ship, on each side, near the bow, is an iron tank the size of a bird cage, filled with salt water. In this tank hangs a delicate transmitter which picks up the bell sounds as they come through the water, and transmits them to a telephone receiver in the pilot house. By means of a switch the navigating officer can listen either to the port or starboard transmitter, and when he hears the sound more clearly on port than on starboard, he knows that the bell lies to port, and vice versa, and when the sound is equally clear on both sides the bell lies dead ahead.

It is to be noted that it is not necessary to cut a hole in the ship in order to instal the receiving apparatus. The tanks are simply clamped against the skin and the sound passes through the skin into the tank without apparent diminution. If necessary, a ship can be equipped while at sea, for the work consists simply in attaching the tanks, hanging the transmitters and running the wires to the pilot house.

TURBINES OR MOTORS IN SHIPS.

Translated from "Nauticus," 1908. Published in "Journal of the Royal United Service Institution," March, 1909.

The following is an extract from the above article and shows the state of engineering opinion on the question of marine gas and oil motors in Germany. An extensive discussion of the same subject by Capt. A. B. Willits, U. S. N., in the December, 1908, number of the "Proceedings of the U. S. Naval Institute" serves to reflect naval engineering opinion on the subject of gas-engine propulsion in the United States.

INDIRECT PROPULSION BY STEAM TURBINES.

PROSPECTS OF THE DIRECT METHOD OF PROPULSION BY TURBINES.

If an opinion is to be given as to the future of steam turbines, it would be to the effect that they will be generally adopted for all fast ships, especially such as combine great speed and high engine power with a comparatively small displacement. Difficulties confront their introduction in slow, mainly cargo-carrying, steamers, and also in ships which, in addition to great speed, are required to have an economical steam consumption at reduced speed and good maneuvering powers.*

Electrical Transmission.

In order to get over the above-mentioned difficulties, it has already been frequently proposed to introduce electrical transmission between turbine and propeller. Such an arrangement would have the advantage that an economically-working turbo-dynamo running at a high number of revolutions per minute, and a propeller running at any desired lower number of revo-

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*This applies properly also to battleships and the best solution for propulsive machinery on battleships appears to lie in the combination system using reciprocating engines in conjunction with turbines.

lutions, could be provided. Moreover, with direct current, as with single-phase reversed current, the regulating of the number of revolutions of the motor within wide limits and without much loss of energy would be possible. Further, no special astern-turbines would be necessary. This question was fully dealt with in "Nauticus" for 1906 (p. 472, *et seq.*).

Up to the present, however, electric motors of several thousand H.P., capable of being regulated, have not been constructed. The employment of electrical transmission must, therefore, at first be limited to low powers and specially suitable cases.

In a paper read before the Shipbuilding Society in November, 1907, on "Electrically-driven Propeller," Schulthes excludes torpedo boats and cruisers at the outset from electrical transmission, and rightly looks to its employment in slow ships. But when he states that direct turbine propulsion is unsuitable for ships like the *Lusitania*, we cannot agree with him, especially as electrical transmission for such high powers cannot be introduced in the present position of electrical engineering, nor is it to be expected in the near future.

For a twin-screw cargo and passenger steamer, with an engine power of 6,000 H.P. at the propeller shafts, Schulthes roughly calculates the economies effected by electrical transmission to be as follows:—In weight, 480 tons; in space, 38,496 cubic feet; in coal, £484; and in oil, £567 per annum. The engine-room personnel can, in his opinion, be reduced by from 1 to 2 men per watch.

Unfortunately, the cost of constructing the installation is not given. It might be considerably higher than for an ordinary set of reciprocating engines and still be more economical, as the additional first cost would be more than made good by the saving in working expenses.

The German Navy is in a position to practically test elecal propulsion on a large ship. The salvage ship for submarines constructed in Howaldt's Yard at Kiel is fitted with this system. The two turbo-dynamos, which are together of 1,200 H.P., and run at 2,500 revolutions per minute, are in-

stalled on the lower deck. They supply current to the propeller motors placed in the after part of the ship, and also serve for charging the accumulators of the submarines. At 200 revolutions the propeller motors each develop 600 H.P. at the propeller shafts, and give the vessel a speed of from 11 to 12 knots. Each propeller can be driven by a separate turbo-dynamo, or both propellers can be simultaneously driven by one turbo-dynamo only. The motors are regulated from the bridge. The ship can, therefore, be maneuvered direct from the bridge without any orders being sent to the engine room.

In addition to testing the electrical method of propulsion, the experiment will perhaps also throw some light on the propeller problem, as this method permits measurements to be easily taken.

A special type of electrical transmission is the "del Proposto" system, which will be referred to later in discussing internal-combustion motors.

With this system, electrical transmission is only used for maneuvering and going astern; for full speed the propeller shaft is connected with the driving engine itself by an electro-magnetic or mechanical coupling. The arrangement has the advantage that electrical transmission only requires to be occasionally used for high powers, but the movable coupling is a disadvantage that prevents the employment of the system for very high powers.

This disadvantage is avoided by an arrangement patented by the firm of Brown-Boveri, in which an electro-motor, which is rigidly coupled with the propeller shaft and receives its current from a turbo-dynamo installed in another part of the ship, is provided as the driving engine for cruising speeds and for maneuvering. When the electro-motor is in use, the main turbine runs without load in vacuum; for longer periods, it can, however, be disconnected.

An improvement of the propeller efficiency through electrical transmission would not, of course, come into question with the two last-named systems, as the propeller must be con-

structed for a high number of revolutions in view of its being driven direct at high speeds.

Hydraulic Transmission.

Recently it has been proposed to make use of hydraulic transmission. In this system the steam turbine drives a high-pressure rotary pump, and this drives a water turbine installed on the propeller shaft. The speed could be regulated either by disconnecting some of the stages of the rotary pumps, which are divided into several stages, by working with several speed stages in the water turbine, or by the employment of various turbine wheels of increasing diameter. For going astern special rings of blades would be necessary.

For such hydraulic transmission Langen, in "Schiffbau,"* calculates the following efficiencies:—Steam turbine, 72 per cent.; rotary pump, 80 per cent.; "Pelton" wheel, 85 per cent.; propeller, 65 per cent.; altogether, therefore, 32 per cent.

For electrical transmission the following may, according to the same author, be reckoned:—Turbines, 70 per cent.; power transmission, 90 per cent.; propeller, 60 per cent.; altogether, 38 per cent.

The total efficiency of a propeller drive with reciprocating engines amounts to about 30-32 per cent., with direct turbine drive about 32-34 per cent.

The efficiency of all three methods of propulsion is, therefore, approximately equal with full load; electrical transmission is the most favorable. The economical advantages of electrical and hydraulic transmission are more conspicuous at reduced speeds, as with both methods of transmission the efficiency remains approximately the same, whilst with direct turbine drive it falls considerably.

In comparison with electrical transmission, hydraulic transmission, which has a somewhat lower efficiency, has the advantage that its utilization for higher powers presents fewer

* "Steam Turbines in Ships," von Langen, "Schifbau," 1907, p. 356, *et seq.*

difficulties. An arrangement for cruising speeds only can, of course, be provided with it, similar to that proposed by Brown-Boveri for electrical transmission.

DEVELOPMENT OF MOTORS FOR SHIP PROPULSION.

Whilst steam turbines have been used in ships for installations of the highest power, the internal-combustion engine has, up to the present, been limited to low powers and to small craft. On shore, however, in the form of a large gas engine, it frequently successfully competes with the turbine.

The utilization of motors in boats was fully discussed in last year's "Nauticus." There is nothing of importance to be added.

The construction of the motor is tending more and more to emancipate itself from the influence of the motor car and to assume the approved form and arrangement of the steam engine, which has developed from the heavy land engine to the light marine engine, specially exemplified in the engines of torpedo boats. The development of the motor has taken the opposite course. Undoubtedly great progress has been made, but the cutting down of the weight, as was necessary in motor-car construction, is very objectionable and quite unnecessary in boats for practical use and not for racing, as the saving in weight possible in the case of a seaworthy boat of normal speed is much too small in proportion to the displacement. The main necessity is absolute reliability. It must be remembered that the demands made on a boat's motor are much greater than those made on the engine of a motor car. Whilst the latter is only required to work at its highest power for shorter periods, and is frequently getting rests when going down hill or during stoppages on account of road obstructions, the boat's motor must be able to run continuously at full speed. The matter has not been sufficiently considered from this point of view, with the result that many breakdowns have occurred which might have been avoided if the various parts of the engines had been sufficiently strong.

Improvement is still needed in the system of ignition, particularly the sparking plugs, which do not always withstand the high temperatures and are very liable to foul, especially when petroleum is used.

It is, therefore, so much the more to be regretted that the only motor which works without such a system of ignition (the Diesel motor) has only been made use of for boats to a very limited extent. With it the air is compressed until over the ignition temperature of the fuel and the latter is injected into the cylinder in a finely-sprayed condition. The combustion is thus uniform and perfect; this motor can, therefore, work with heavy oils, which cannot be used in "explosion" motors.*

The latter work best with light oils, like benzine. This is, however, very expensive, and its introduction on board a vessel much too dangerous as regards fire; it cannot, therefore, be considered for warships' boats. Petroleum may, from this point of view, be considered suitable, but, as already stated, it fouls the sparking plugs, and also the cylinder, thus injuriously affecting the piston in consequence of the high combustion temperatures. The considerable heating of the piston in conjunction with the unconsumed residue frequently leads to early firing. These difficulties increase with the diameter of the cylinder, so that for larger motors it is proposed to carry cooling water through the piston rod.

For ships' motor boats in our Navy benzol spirit—a mixture of about 75 parts 90 per cent. spirit and 25 parts benzol—is generally used. As regards its introduction on board, this fuel is not more dangerous than petroleum; the consumption per H.P. is approximately the same, the cost per kilogram somewhat higher. The disadvantage of the pure spirit that, in the case of combustion with too small a quantity of air, acetic acid is formed, which leads to the formation of rust in the cylinder, is diminished with the benzol mixture. For starting the motor, benzine, as with petroleum, must generally be made use of; the carburettor must also with this fuel be heated by the exhaust gases. So far as the size of the motor permits,

* See "Test of Diesel Motor" in succeeding article of this number.

starting is done by hand by means of a special starting crank, as with motor cars. Larger motors are started by compressed air, which is stored in receptacles, or an explosive mixture is injected into the cylinder. Sometimes a small explosion motor is specially installed for starting the larger.

Electro-motors are also used for starting, if, as on submarines, accumulators are already present for other purposes.

For reversing the propeller shaft, reversing gear is used, or propellers with reversible blades are fitted. With higher powers, where these arrangements are inconvenient, the motors themselves are reversed by means of compressed air. Special reversing gear must then be fitted to the cam shaft.

A self-acting reversing arrangement, which is, however, only suitable for smaller powers, is fitted in the Swedish reversing motor, which the firm of Howaldt, of Kiel, are licensed to construct; the reversing is effected through early ignition during the compression period and guiding the reversing apparatus into a curved disc of special shape. Of course, the reversing can only be carried out whilst the motor is running.

Reversing the propeller shaft by means of electrical transmission, as, for example, in the del Proposto system already mentioned above, is perfect in action, but such an installation is expensive and difficult to set up. The motor, always running in the same direction, drives a direct-current dynamo; this supplies current to an electro-motor placed on the propeller shaft. By altering and reversing the field of the dynamo the number of revolutions and the direction of rotation of the motor can be altered as desired. Del Proposto only uses this transmission for maneuvering and going astern, and, therefore, only occasionally at full power. At full speed ahead the motor is coupled direct to the shaft by means of an electro-magnetic coupling.

Electrical transmission can, of course, be continuously made use of, if, for example, the energy of a dynamo is utilized in several propeller motors, or the energy of several motor dynamos is combined in one propeller motor. Moreover, storage batteries can be added to the installation; the internal-com-

bustion motor could then be stopped and these alone used for low powers, or they could be utilized as an additional source of power for full speed. An example of such an arrangement is to be found in the motor boat *Ellen*,* constructed at the Siemens-Schuckert Works, and others, with many variations, in submarines.

The utilization of motors in ships' boats and warships of various kinds was fully discussed in last year's "Nauticus."

The introduction of motor boats as ships' boats has made further progress in all navies. In the German Navy, in particular, experiments with the various types were so successful that a large number of ships' motor boats are shortly to be supplied. As was previously the case with ships' steamboats, it is proposed to supply one type only, in order to simplify working and repair.

In all large navies submarines offer an equally wide field of employment for motors. There will be some fairly difficult problems for motor constructors to solve in this direction, as the single engine sets have already grown to powers of 300 H.P. The difficulties are much greater from the fact that only petroleum is used, as lighter oils cannot be employed without danger in the closed spaces of submarines, and, moreover, on account of the special condition of stowage, a fuel whose specific gravity is less than that of water must be chosen.

In addition to fitting motors in submarines, certain navies, especially the English, are considering their installation in coastal torpedo boats. Particulars concerning one such boat were given last year.

The problem is quite solvable; from the military point of view there is something attractive in the idea of constructing at small cost a large number of such boats, which can be carried by rail from one port to another. It must be remembered, however, that these boats can never replace sea-going torpedo boats, and that the submarine is a much more versatile and effective weapon for coast defence.

In the mercantile marine the motor finds employment in

* See Year Book of the Shipbuilding Society, 1908, p. 267, *et seq.*

tenders, ships' boats, cargo boats, ferry boats, etc.; it is also used in pleasure boats and yachts, and, to some extent, as an auxiliary in sailing yachts and merchant vessels.*

One of the largest engine installations of this kind is the 500-H.P. benzine motor in the American four-masted schooner *Northland* of 2,047 gross tonnage. The installation, which closely resembles a steam engine, is very interesting. It is a double-acting motor with six 10-inch cylinders, having a stroke of 10 inches. It drives a two-bladed propeller 6.8 feet in diameter and 3.9 feet pitch, which gives the vessel a speed of from 5 to 6 knots. For starting and reversing the motor compressed air is used. The benzine is stored alongside the engine in two tanks of a total capacity of 812 cubic feet. Two smaller benzine motors, coupled to dynamos, are installed for generating current for several cranes and for lighting the vessel.

The Diesel Motor.†

Whilst in the types of motors just considered, the so-called explosion motors, the pistons are driven by a single explosion, in the Diesel motor the work is done by a series of explosions. This motor can, therefore, in contrast to the explosion motor, be called an equal-pressure motor.

This method of working, in conjunction with the system of introducing the fuel, the injecting in a finely-sprayed condition, results in extraordinarily perfect combustion. As, moreover, there are no special vaporizing or ignition contrivances, and the fuel is exploded by being injected into air heated over the ignition temperature of the oil by compression, heavy crude oils, whose employment in the "explosion" motor is quite impossible, can be used with the Diesel motor.‡

The greater economy in working resulting from the use of

*The question of auxiliary motors for sailing vessels is fully dealt with in the 1907 and 1908 Year Books of the Shipbuilding Society.

†See article "Test of Diesel Motor," in this number.

‡See an article on "The Employment of Liquid Fuel in Ships" in "Nauticus" for 1903; and also "The Present Position of Caloric Engines and the Question of Liquid Fuel, with special reference to the Diesel Motor," by Rudolph Diesel, Muenchen ("Journal of the Society of German Engineers," 1903, p. 38).

such oils, and the greater safety in stowing them, permit the Diesel motor to be regarded as specially suitable for ship propulsion. It is, therefore, surprising that it has only been made use of to any extent in a number of vessels on the rivers and lakes of the Russian oil territory, where the presence of the cheap fuel for which it is suited has probably conduced to its employment.

On shore it is more frequently used; about 1,300 sets, with 1,860 cylinders, and of about 106,000 H.P. have been installed by the Nürnberg-Augsburg Engine-Construction Company alone.

The reason for its having been so little used up to the present for ship propulsion is undoubtedly its too great weight. Recently, however, its constructors have been making efforts to reduce this. In last year's "Nauticus" (p. 425) particulars were given of a reversible 100-H.P. Sulzer-Diesel motor, which weighed about 5 tons without shafting and propeller.

The results of experiments with a rapid-running Diesel motor constructed for use in ships have recently been published in the Journal of the Bavarian "Revision" Society (No. 1, 1908); this motor is constructed for 300 H.P. with 400 revolutions, and weighs about 10 tons. The weight is understood to include starting and injecting apparati, cooling arrangements, lubricating and cooling-water pumps. It is not much greater than that of an equally large "explosion" motor, as a Körting petroleum motor of equal power, running as a two-phase motor at 550 revolutions, weighs about 8.9 tons.

The motor consists of four single-acting and four-cycle cylinders, with cranks set at an angle of 180°. On a level with the four cylinders is fitted the two-stage air pump, common to all four cylinders; this draws in air from the atmosphere, and is regulated by the throttling of the air drawn in. The four fuel pumps are also placed together, and are driven by the reversing shaft. Each cylinder has an inlet, an outlet, a fuel, and a starting valve. At the end of the crank shaft are fitted two small oil pumps for lubricating purposes; the oil is used again after being cooled.

In addition to the cylinders, the exhaust tubes are cooled

by two pumps driven by rods from the piston, so that the hot exhaust of the motor into the surrounding atmosphere is very small.

As the motor is constructed for the propulsion of vessels, it has no speed regulator, but simply a safety regulator, which is intended to prevent racing; its charging and, therefore, the number of revolutions, are controlled by hand. It is not reversible, being intended for submarines, where it acts on the propeller shaft by means of electrical transmission. For a reversible Diesel motor the two-phase system, on which the Sulzer-Diesel motor mentioned above is constructed, would be preferred, as with it the number of reversing valves is smaller.

In the very thorough power and fuel-consumption experiments the motor was coupled to a direct-current dynamo. The fuel used was Galician gas oil.

Although the motor was only constructed for 400 revolutions and 300 H.P., its number of revolutions was increased to 500, and its effective power to 400 H.P.

With the alteration of the number of revolutions from 250 to 500, with various mixtures and with powers varying from 100 to 400 H.P., the motor worked with perfect combustion and without trouble of any kind with the distributing mechanism or the driving gear.

Its fuel consumption and heat utilization were little, if at all, inferior to those of the slow-running Diesel motors; its mechanical efficiency is, from the experiments, equally good.

We have considered somewhat carefully the experiments made with this motor, because they appear calculated to throw new light on the employment of the Diesel motor, which is well worth striving for, especially in the case of submarines.*

The Suction-Gas Motor.

Whilst the motors so far dealt with are worked by a mixture which is produced from oils, the suction-gas motor makes use of a gas produced from solid fuel (anthracite, coke, coal),

*The Diesel Motor, more than any other gas or oil engine, appears to have promise of commercial success for ships' propulsion. For this reason its development should be watched with interest by naval engineers. Already has this motor been used for driving naval dynamo engines and also for propelling vessels of considerable size.

this gas being drawn in from the generator by the motor itself.

The method of producing the gas is as follows:—A mixture of steam and air is led through a glowing mass of coal. The carbonic acid produced by combustion of the oxygen of the air is reduced to carbonic oxide; hydrogen is formed from the steam. On the installation being started, a draft is produced through the lowest layer in the fuel receptacle by a fan worked by hand or by a small motor; the gases developed pass through a steam generator, the steam from which is led under the grate by a pipe with openings at the end in the form of nozzles. Through the suction effect of the flowing steam, air is simultaneously drawn along with it. In this way the gas-production process, which is fully developed through the suction effect of the engine after it is set going, is started.

Before the gas reaches the engine it is led through a cleanser. In land installations this is filled with coke, which is continuously sprinkled with cold water. The impurities contained in the gas are here removed. In ships, where a coke cleanser would be too heavy, the cleansing must be carried out in another way. In a gas producer for an 80-H.P. Capitaine ship's motor, for example, the cleansing was effected by the gas being led through a chamber in which water is transformed by air into its most finely sprayed form.* The mixture of water and gas produced by the streaming through of the gas is then again separated in a centrifugal cleaner, where the particles of tar and ashes contained in the gas are removed together with the water.

Although it is possible, by using anthracite, brown coal briquettes, or best coke, to produce a comparatively clean gas, if bituminous coal containing much tar is used, the difficulties are very considerably increased. In ships, however, this must be provided for. The use of such a fuel renders a considerably larger and more complicated cleansing apparatus necessary.

* See the Year Book of the Shipbuilding Society for 1905, in which there is an article by Capitaine on "The Gas Engine for Ship Propulsion," which goes fully into the problems connected therewith. Of course, as inventor and constructor of such engines, he is rather biased.

Moreover, the vaporized water cannot be recovered, so that in ships a specially-constructed vaporizer must be employed.

The great hopes which were centered in suction-gas engines in view of the considerable success obtained with large gas engines, the gas for which was produced by means of blast and coke furnaces, have not been fulfilled. The chief difficulty has been the cleansing of the gas, especially when cheap coal is used. The use of expensive fuel makes the economy of the suction-gas engine doubtful, especially as its high efficiency depends on its being continuously run with full load. The loss from the generator when the engines are stopped may amount to 20 per cent. of the consumption at normal power.

Under these circumstances the use of suction-gas installations on shore has somewhat declined, and is limited to cases in which the conditions are specially favorable for providing a suitable fuel.

Suction-gas engines have, generally speaking, not yet been introduced in ships, except for a few experimental installations. Their employment is at present limited to a few boats with Capitaine motors, among them a Hamburg tug, a yacht constructed by Thornycroft, and a few vessels on the Rhine fitted with Otto engines at the Deutz gas-motor works.

Recently experiments have been commenced by the English Navy with a Beardmore-Capitaine motor in the former gunboat *Rattler*. The motor has five cylinders, 20 inches in diameter and of 24-inch stroke, and develops 500 H.P., giving the vessel a speed of from 10 to 11 knots. It is started with the assistance of a mixture of gas and air at high pressure. For going astern the shaft is reversed. The weight of the engine installation, inclusive of an auxiliary boiler for pumps, etc., is said to be 94 tons, as compared with the 150 tons of the former reciprocating engines, with boilers; the saving in coal is about 50 per cent. In the weight given the fuel supply may be included, and the saving in weight be merely due to the smaller amount of fuel required with the suction-gas installation.

Motors in Large Vessels.

If the present development of motors as described above is studied, it will appear premature to speak of their employment in the largest vessels. The question is, however, constantly being discussed in the technical and daily papers, and its solution spoken of as being very near.

McKechnie's Proposals.

A paper which Mr. J. McKechnie, Director of Engine Construction at Vicker's Works, read at the meeting of the Institution of Naval Architects in the spring of 1907 on the "Influence of the Engines on the Artillery Power of Modern Warships," called forth special discussion.* It was not so much the lecturer as his audience who developed this subject and lent importance to the meeting, especially as regards the introduction of motors as the main engines, so that shortly after the press of other countries took the matter up.

McKechnie considers the advantage of motors to lie not in technical superiority or greater economy, but chiefly in the possibility, through the absence of funnels, of producing more favorable conditions for mounting the heavy guns.

He takes as the basis of his scheme a battleship of about 16,000 tons displacement. The gas-engine installation of 16,000 H.P. is divided into 3 groups, which are placed in 6 compartments. The ship has 4 propeller shafts, each of which is driven by a 10-cylinder vertical gas engine. The gas producers are placed in the two compartments amidships, whilst forward there are four sets of air-compression pumps driven by gas motors, which presumably are to serve for starting the main engines. The remaining auxiliary engines—dynamos, steering-gear capstans, pumps—are driven by special "explosion" motors using liquid fuel.

Of course, the proposer of this scheme claims for motors considerable economies in space and weight. These statements

*See Marine "Rundschau," 1907, p. 632.

are not, however, of much interest, as they are merely rough estimates.

Quite apart from the practicability of such an installation, with which we will deal later, the scheme is unsound, because it rests on a false hypothesis. McKechnie assumes that with motors, funnels are superfluous. The enormous volume of combustion gases emitted by a 16,000-H.P. gas-engine installation must be got rid of somehow. They cannot be released above water at the side or aft, as that would make it impossible to stay on deck. Neither can they be released under water, as the pressure of the water would reduce the efficiency of the engines; moreover, such large underwater openings—50 to 80 square feet—would be dangerous.

It is a widely spread misapprehension that funnels are essential to a steam-engine installation, and not to a gas-motor installation. If the obstacles mentioned above did not exist, a steam-boiler installation of this power could be worked without funnels, as the air pressure produced under the grates by fans is so high that the small pressure height of the funnels need not be considered in comparison with it. Admiral Fremantle, therefore, was not correct when, in the interchange of views concerning this scheme, he maintained that the destruction of the funnels in action would seriously reduce the power of the steam engine.

In addition to it not being possible with such a gas-motor installation to dispense with exhaust tubes of the nature of funnels for leading away the gases, the provision of shafts for ventilating the engine rooms must also be reckoned with, especially as there is not only the hot exhaust from the motors, but also the possibility of poisonous gases being emitted, to be provided for.

For these reasons the above-deck structures with internal-combustion engines must be similar to those with steam engines, and the gun arrangement proposed by McKechnie becomes impossible.

Even if this main object could be attained, far greater difficulties would be met with in introducing such large internal-combustion engines in ships.

As McKechnie himself stated, his conviction of the practicability of such large internal-combustion marine engines is based on experiments made by his firm with an 800-H.P. installation. The late Director of Naval Construction, Sir William White, during the discussion, rightly pointed out that such a jump from 800 to 16,000 H.P. is rather a sporting proposal.

Schemes similar to McKechnie's are sure to be continually put forward. We will, therefore, further consider the practicability of such large internal-combustion engines for ships in the present state of motor engineering.

Practicability of Large Oil Motors.

Of oil motors, only those which use heavy oils can be taken into consideration. With benzine, spirit, and even petroleum, the danger of fire is much too great with the large quantities it would be necessary to carry; moreover, they are too expensive. Lamp petroleum, for example, costs about 1.06d. per lb.; this is ten times as much as the cost of coal. Therefore, even if the petroleum motor utilizes its fuel two to two-and-a-half times better than the steam engine, its working costs are still four to four-and-a-half times as great. "Explosion" motors being dependent on this fuel, as we have seen above, must therefore be left out of consideration.

There remains, therefore, the Diesel motor, which can use heavy and cheap oils, and, in addition, possesses the advantage that it works without special ignition arrangements or vaporizer, as a result of which it is very reliable.

Like all oil engines, it has, however, the disadvantage that the cylinder diameter cannot be increased as much as desired, and brought somewhat near that usual with steam engines. The difficulty arises from the fact that the motor works at a considerably higher pressure than the steam engine, and that in consequence, when increasing the cylinder diameter, powers are finally arrived at which are impossible with crank drive. Moreover, as already stated, the difficulty of cooling the piston increases with the diameter.

With Diesel motors the greatest power of one cylinder is 200 H.P., with about 140 revolutions. For an engine installation of 16,000 H.P., 80 cylinders must, therefore, be provided, and valves and distributing mechanism repeated for each cylinder. With the arrangement of a Diesel motor already described, this alone would necessitate 320 valves.

As an installation so sub-divided cannot work direct on the propeller shafts, the only way out is electrical transmission, a central station being arranged in which Diesel motors drive a large number of dynamos, the current being led to a small number, at the most, perhaps, four, of propeller motors.

Such a system was actually proposed by a Russian engineer, Lieutenant Philippow, in 1905, and was described in "Schiffbau."

This system provides for 30 Diesel-motor dynamos, with a total of 16,000 H.P., which is divided between four electro-motors of 4,000 H.P. each, working at 120 revolutions. Two electro-motors work on one shaft.

Even if the construction of these large propeller motors is assumed to be possible, there still remains the difficulty of maneuvering with them, as this is increased by the large number of prime movers. The working of the numerous prime movers will scarcely present more difficulties than an equally large steam-engine installation, with its numerous boilers and the pumps and auxiliary apparati necessary for the working of the engines and boilers. Problems connected with weight and space are capable of satisfactory solution with the progress already made in the construction of fast-running Diesel motors, especially as, in comparison with steam engines for the same radius of action, a considerably smaller supply of fuel would be necessary. With such an installation there would only be an advantage as regards economical working if cheap crude oil could be used. Sufficient experience has not yet been obtained concerning the continuous reliable working of Diesel motors with such crude oils, and, moreover, this fuel is not to be obtained everywhere in the quantities required, like coal. In comparison with coal, the storage of liquid fuel on board ships

is difficult, as the oil compartments are, in practice, generally found to leak. In addition, the absence of coal removes an important means of protecting a ship, and even heavy oils, in case of injury to the hull from grounding or from a torpedo, constitute a source of danger which is not to be underestimated.

The Practicability of Large Suction-Gas Installations.

The last-mentioned disadvantage does not appear with suction-gas motors, which, in addition to Diesel motors, alone come into consideration for the propulsion of large ships. They have, however, the disadvantage that they require special gas generators and cleansers. The difficulty of cleansing the gas has already been spoken of. On account of this difficulty and the scorifying in the gas generator, the use of ordinary coal is practically excluded. Fuel like anthracite is not, however, to be obtained everywhere in sufficient quantities, and it would make the cost of working so high that the only reason for introducing suction-gas installations in ships—the greater economy—would disappear. Moreover, apart from the high cost of the fuel, the economy would be rendered doubtful by the great waste in the gas generator when the engines were stopped or running at a low speed.

Further difficulties are to be met with in conducting the gases from the generators to the engines. The gases are poisonous; every leakage from the conducting pipes may therefore be dangerous to the crew in the narrow engine rooms. It has already been proposed to surround the pipes with a jacket of compressed air, but for a long system of pipes this would be rather troublesome and difficult.

The suction-gas engines have the advantage over oil motors that they are practicable up to powers equal to those of modern steam engines. Of course, engines of this power must be gradually developed for use in ships, as the experience gained in the construction of gas engines of several thousand H.P. for use on shore is not sufficient.

As compared with steam engines, gas engines would always

have the disadvantage that they are not directly reversible, and require special auxiliary installations for reversing and for starting. In large installations, electro-motors, in conjunction with accumulators, are not suitable for this purpose; in these only compressed air can be made use of. The dimensions of the air compressors and receptacles that would be necessary in a warship steaming in company are well illustrated by the rough calculation that for twice reversing an engine installation of 16,000 H.P., about 810 cubic feet of air, at a pressure of 60 atmospheres, would be necessary. In McKechnie's scheme a very considerable space is allowed for the compressor installation, but it may not be adequate.

If all these installations, the gas generator with its cleansing apparatus, the complicated system of pipes, the air compressors for starting the engines, and the numerous auxiliary apparati, are included, it would appear probable that such an installation would not be lighter, but heavier, than a steam-engine installation.

CONCLUSIONS.

Advantages of Internal-Combustion Engines.

For large ships, as we have seen, neither advantages as regards economy nor any considerable saving in weight and space are to be expected from internal-combustion engines. The reduction in the amount of fuel necessary to be carried, and the consequent decrease in the size of the bunkers, constitutes the only advantage as regards weight and space.

Other military or technical qualities peculiar to internal-combustion engines, which will lead to their further development, have yet to be discovered.

An undoubted advantage is the absence of smoke, which makes it possible to approach the enemy without being observed. This can, however, be practically equally well attained with a steam-engine installation by using oil fuel.

Oil motors are always ready, and can be started in a few minutes. Suction-gas motors do not possess this merit. As

we have seen above, the waste in the gas generators when the motors are stopped is rather great. It takes longer to get the gas generator going than it does to raise steam in boilers, especially small-tube boilers.

Internal-combustion engines do not strain the engine-room personnel as much as steam engines; there is no longer the boiler installation, which, especially at forced draft, throws such a great strain on the stokers, to be attended to. This, again, mainly applies to oil motors, which automatically develop their highest power without making any special demands on the personnel. In the case of suction-gas installation, the attendance required by the gas generator cannot be much less than that required by steam boilers, especially with large installations, if the fuel receptacle of the gas generator is limited in size in order to effect a saving in weight. The statement made in all commendations, even those appearing in technical papers, of the suction-gas motor as a marine engine, that the gas generator only needs to be filled with fuel once a day, of course, only applies to shore or small marine installations.

Another frequently commended advantage of internal-combustion engines is the absence of a system of steam pipes. In the case of the suction-gas installation, however, there is the much more dangerous gas-pipe system to take its place. Whether leakage from an oil pipe is less probable, and its injury in action less dangerous, may be regarded as doubtful.

If, therefore, we sum up the foregoing, the advantage possessed by all internal-combustion engines is the absence of smoke; in addition, oil motors have the advantage of constant readiness and immunity from trouble in working.

Disadvantages of Internal-Combustion Engines.

These few advantages have a number of disadvantages to counterbalance them; most of them have already been discussed in considering the separate systems.

Difficulties as regards starting, reversing, and large altera-

tions in the number of revolutions, are common to all internal-combustion engines.

In this respect the steam turbine is much more satisfactory. It can be started like a reciprocating engine; its number of revolutions can be altered within wide limits by throttling the steam or connecting and disconnecting pressure stages; finally, the propeller shaft can, comparatively simply, be rendered reversible by the installation of an astern turbine.

From this point of view the introduction of the internal-combustion engine would appear to be a retrograde step. The real retrogression would, however, be the fact that a piston-engine with crank drive, whose numerous transmitting and distributing parts need more attention and repair than the steam engine, was being developed to take the place of the rotating engine, the steam turbine.

Merits of Rotating Engines.

The introduction of the steam turbine for shore and marine use, in conjunction with the development in the employment of electric power, has opened up a great future for rotating engines. There must be very great merits in internal-combustion engines, if engines with crank drive are again to come into favor. That even great economy is not sufficient to ensure this is well shown by the fact that the highly-developed and very economical superheated steam engine cannot compete—at least for high powers—with the steam turbine, and that, with a few exceptions, its adherents have not, up to the present, succeeded in getting it utilized for the propulsion of ships.

If any internal-combustion engine could have a chance of being generally adopted for the propulsion of ships, it would be the gas turbine. This is, however, at present in a purely experimental stage of development, and the results so far obtained, thermal or mechanical, do not warrant the hope that, even for land installations only, a practical gas turbine can be produced in the near future.

Prospects of Internal-Combustion Engines.

The internal-combustion engine, in its present form, and where the conditions are specially suited to it, will, of course, maintain its position, and will find many new fields of employment. Thus, it will probably not only remain the most suitable means of propulsion for ships' boats, small torpedo boats, submarines, and small yachts, but will be more extensively made use of as an auxiliary engine for sailing ships, and for the propulsion of small and moderate-sized, including sea-going, cargo vessels. In these directions much may be expected from the Diesel motor in particular, especially if its starting and reversing arrangements are improved, so that it can be used with direct propeller drive in moderate-sized vessels.

NOTES ON MARINE GAS AND OIL ENGINES.

The following articles on the subject of the use of gas or oil engines for the propulsion of vessels have recently appeared in various engineering publications. They, together with the reproduced translation, article on page 458, will serve to show the many directions in which this subject is being experimented with and the many lines of thought that are being applied to solve the problem of successfully applying the gas and oil engine to vessels of large power.

Some comments on the ideas advanced in the various papers are to be found in the notes accompanying the text.

THE GAS ENGINE AND PRODUCER PLANT AND ITS ADAPTABILITY FOR MARINE WORK.*

The question of the gas engine and producer plant, and its application to marine propulsion, is one that has received a large amount of attention and interest from internal-combustion engineers, marine-engine builders and ship-builders, some of the latter who, notwithstanding the fact that the gas engine and the gas plant is the prime mover in their own works, seem to be exceedingly chary of giving a trial to the gas engine in the boats they build or engine. It is natural that, after their intimate acquaintance with the steam engine and its traditions, which in many cases date from over half a century back, they should be very reluctant to adopt a new type of prime mover which but a few years ago was regarded as only suitable for operating light printing machinery, where power was required not exceeding 10 H.P. The economic law must eventually prevail, and, by reason of severe competition, ship owners will be driven, in the near future, to ask from the builders a cheaper

*Abstracted from a paper read by E. Shackleton, A. M. I. Mech. E., before the Institute of Marine Engineers.

running type of boat as far as fuel consumption is concerned, particularly in the matter of the cargo type, four to five thousand tons gross.

The present steam type of engine employed is no doubt very economical as far as steam goes with a consumption, under very favorable circumstances, of slightly over 1 pound per I.H.P. per hour. The more common range of consumption, however, is in the locality of 1¾ to 2 pounds per I.H.P. per hour. Even if "superheat" were employed, with its attendant wear and tear, it is questionable whether a consumption of 1 pound per I.H.P. per hour could be maintained. The chief objections to a gas engine and plant, from the marine engineer's point of view, are:

Their inability to reverse. Unreliability. Preignitions and backfires. Difficulty in starting. Accumulations of dirt and carbon in cylinders and pistons. Poisonous gas from leakage of gas plant.

To these objections we would say in regard to—

Reversing Difficulty.—This will be dealt with in detail later on.

Unreliability.—There are gas engines at work and which have been at work for the last six years, with periods of from three to six months night and day, without stopping.

Preignitions and Backfires.—In well-designed gas engines, such as those referred to in this paper, under all normal conditions these troubles are very rare.

Starting.—The use of compressed air for this purpose has now made the starting as easy as that of a steam engine.

Accumulations of Dirt and Carbon, as a rule, may be traced to an inferior lubricant or to excessive lubrication, an item that by a little intelligence on the part of the engineer in charge may soon be rectified. If not from this source, the plant, particularly the scrubbers, probably requires looking at, as, under the usual working conditions, a fairly clean gas is delivered to the engine.

Leakage of Poisonous Gases.—Accidents which have occurred under this heading are largely due to the neglect of

common precaution and are extremely rare. The danger arising from the escape of poisonous gas (carbonic oxide) is more likely to occur in starting producer plants which work under pressure, and even during the running of such systems, should there be any leakage in the plant. In the case of suction plants, which are operated by suction from the engine, the period of danger from the escape of poisonous gases is limited to the ten or fifteen minutes during which the generator is raised to the necessary temperature by the fan. On shipboard a simple system of ventilating fans would reduce any risk to a minimum.

Wear and Tear and Upkeep.—This is certainly an important item, but as far as the most up-to-date experience is concerned the labor and cost have been found to be practically little, if any, more than with steam.

The gas engine and plant appear to be more directly suited to marine requirements than the large oil engine, notwithstanding the extra inducement which the latter offers as being self-contained. It is, however, very questionable at the present moment whether the problem of dealing with every description of crude oil, as a fuel in an oil engine, has been definitely solved, and even in such event it is very doubtful if there is any real advantage over the producer plant in power cost. It must also be borne in mind that the most suitable type of engine for operation with crude oil is somewhat complicated and expensive to build. In the scheme proposed, the writer would like to emphasize the fact that he has no individual axe to grind for any particular type of plant, engine, dynamo or other accessory, and that while he has of necessity selected certain types as particularly suited for his scheme, no reflection is intended by non-reference to other plants, engines, etc., of high merit. Specialization is extremely necessary to the ultimate success of the gas boat, and only by such blending of a combination of shipbuilders, marine-engine builders, gas-engine and plant makers, and electrical engineers, each bringing their varied experience to bear in construction of the boat and her engines, could the desired results be obtained.

With these prefatory remarks, the scheme referred to will now be described in detail:

One main set of Westinghouse type, vertical tandem, enclosed gas engines, as illustrated, of 700 B.H.P. Two secondary sets Campbell type, crank-chamber gas engines, each of 250 B.H.P. Each of the three engines coupled to a dynamo with two motors, either of 400 kilowatt or of 500 kilowatt, and the usual main switchboard, with accessories. The steering gear would be operated by electric motor of suitable design and power. The usual pumps, centrifugal type in this case, would also be operated by electric motors for bilge, ballast and circulating, the latter being employed for the cooling water of the gas engine. A Campbell oil engine, 6 B.H.P., to be used for ship lighting when in port, as referred to later.

The writer has not attempted to go into the smaller details, as, of course, it is impossible to specify correctly until the dimensions, space and conditions of a steamer so fitted can be definitely decided on by the shipbuilders.

The gas plant suggested is of the suction type, having four generators, and capable of supplying gas for the engines of the Dowson, Crossley and Mersey types, and these Mr. Shackleton described. He pointed out that boilers of the Wilson exhaust type, also acting as silencers, supplying steam for suction plant and for condensing purposes, using sea water, would be required, and one small boiler for raising steam when plant is started and when the Wilson boilers are not available.

Repairs.—The low cost of repairs, he continued, varies somewhat, but the following may be taken as approximately correct:

For 100 horsepower, about £4 per annum.
For 200 horsepower, about £6 per annum.
For 300 horsepower, about £9 per annum.
For 400 horsepower, about £12 per annum.
For 500 horsepower, about £15 per annum.

The cost of cleaning and repairing the boilers used for steam engines is much more serious.

Inability to Reverse.—Reversing is beyond doubt a most important function in marine work, and it must be an operation that can be carried out with certainty and without delay. To reverse a gas engine of any size would, and will be, an extremely complicated process. While it is recognized that a reversible gas engine is an accomplished fact, it is probable that, under the very onerous conditions of marine work, the increased wear and tear and complication of reversibility would only be obtained by a sacrifice of efficiency and reliability. Nothing could be more fatal to the progress of the marine gas engine than increased working parts where efficient simplicity is desired. As the safety of a vessel sometimes hangs on her ability to go astern promptly, it is at once obvious that this is a point which cannot be missed. With the electric drive proposed, the reversing process is, of course, carried out by the motors attached to the propeller shafts.

Reversing Gear for Propellers.—Although the writer advocates electric drive, it is clear that to shipowners who do not require more than 600 or 800 B.H.P. the expense of such type of drive would probably deter them from trying a steamer fitted with a gas engine. There are on the market several reversing friction clutches which should, possibly in a modified form, do all that is expected if the full power were not desired for going astern. There is no reason to suppose that they would not perform their duties satisfactorily. Where twin screws are employed, reversing might be confined to one propeller, which, under all ordinary routine conditions, should prove satisfactory, although being somewhat slower in action. In such a case as this the proposal submitted as to electrically driven winches would still be carried out except in the case of a sailing vessel.

The Coil Clutch Co., Ltd., now construct reversing gears up to 2,500 H.P., and have made several gears of heavy power transmission capability for marine work. The gearing is always in mesh, consequently this clutch is perfectly silent when running ahead, and almost noiseless when going astern. It has one positive speed ahead and astern, both controlled by

a hand wheel, or by a hand lever if preferred. When desirable the speed can be regulated and the boat run to dead slow by manipulating the starting gear.

The enclosed type of gas engines recommended for consideration in the scheme appears to be admirably adapted for marine conditions. They are well balanced, positively lubricated, and, being enclosed, any leakage of gas that might pass the pistons is confined to the case. Their speed is higher than certain types of gas engines, but at such speeds gas engines of the type referred to run as a rule steadily without great vibration. It is not anticipated that the sole plate or bed foundation for these engines on shipboard would present serious difficulties to the shipbuilder. The system of governing these, compared with steam engines, is decidedly in their favor, there being no hit and miss, but positive throttling by varying the quantity and quality of the explosive mixture. The engines of the tandem type have also proved themselves to be very reliable and also admirably adapted for the class of work.

For the purpose of starting these engines, *i.e.*, charging the compressed-air reservoirs, it is proposed to use the small oil engine, which is also used for ship lighting. It is not intended, for the limited power required for a 3,000 or 4,000 tons gross gas-driven steamer, to introduce the bituminous producer. While it is recognized that such a producer would undoubtedly be a great advantage for marine purposes, the writer feels satisfied that anthracite is now sufficiently available to economically answer all the requirements of a cargo boat working on a fixed route. This fuel is available outside Wales, in America, New Zealand and various parts of the Continent. If the same were not available recourse could be made to good coke. As far as can be seen it is, moreover, questionable whether, for powers not exceeding 2,000 B.H.P., the bituminous plant would really be such an advantage as would otherwise appear. Outside its main feature, the ability to use common fuel, it is cumberous, decidedly more complicated in its action, requiring considerably more attention, and is almost twice as heavy as the suction gas plant. Ammonia recovery would also be out

of the question on shipboard. Whilst it is recognized that ability to use a common fuel is certainly a great deal in its favor, it appears to the author that the simplicity of the suction plant will, in the long run, outweigh such advantages for moderate powers and under marine conditions. In making comparative tables of costs of a gas-driven and a steam-driven steamer the writer has in mind that anthracite is dearer than Welsh steam coal, and also than North Country coal, but, taking into consideration the pros and cons, this is not an all-important factor. It would doubtless, however, be necessary to use a bituminous producer plant for powers exceeding 2,000 B.H.P., but this paper recommends a trial of a boat of moderate powers, having in mind the maxim, "learn to walk before you run." The plants shown are simple in operation, reliable and economical, and, as far as can be foreseen, marine conditions and the motion of the boat are not likely to greatly affect its operation.

The fairly regular load in marine work would suit the producer plant, and the fact that such plants would require to work continuously is favorable to the producer; in fact, a more uniform gas of even quantity is likely to be produced with corresponding fuel efficiency than would be the case where the plant is shut down at the end of a day's work. The bogey of tar troubles, etc., is very much overblown, and under the intelligent eye of the average marine engineer little or no trouble should arise from this source. It is proposed to have the generators in four small units, this being considered desirable, so that, in the event of any repair or cleaning being required, one may be shut down till this has been effected without interfering with the production of gas from the rest of the plant. In the event of anthracite not being available, good gas coke, which can be obtained almost anywhere, may be used with good results on a slightly higher fuel consumption. Coke, however, requires more attention at the generator, and the gas made from it is not so clean as that made from anthracite. The plants under consideration are suitable for either fuels and give a gas very free from tars. The scrubbers are made extra

large to cope with such an emergency. Sea water would be quite unsuitable for direct use on the gas plant, as the vaporizer would quickly become encrusted with salt and cease to make steam. A small steam boiler is installed for starting steam, being available when the engines are running from the Wilson boiler, to which reference is made earlier in the paper.

Objection will no doubt be taken to the proposed speed of the propellers, 250 to 300 R.P.M., as this is, of course, much higher than the present cargo boat. While it is recognized that a low-speed propeller has certain advantages, it must be borne in mind that they are more or less in ratio to the present steam-engine speed, which could not well be higher. The writer is of opinion that where a high-speed propeller is found necessary the shipbuilder would quickly adapt himself to the exigencies of the position. The electric motors for driving the two propellers would, of necessity, occupy more space near the propellers than the present tunnel permits, but this is also a matter which the shipbuilder would allow for without any serious expenditure when the boat was building. Doubtless the cost of the electrical equipment would be heavier than the average steamer, probably £6,000 to £7,000, but, apart from the huge saving in fuel consumption over the steamer, the reduction of strain on the hull due to a short shaft at propeller end and electrical drive, together with the great advantage that in bad weather the very effective method secured by such drive against racing would be invaluable, greatly minimizing the liability of losing propellers in bad weather and giving great frictional reduction compared with the present steam-driven shaft drive. Another objection against the electric drive may be urged on account of the loss of power from dynamo to motor. This will doubtless be in the locality of 15 per cent., and is no doubt an item of some importance; but let it be considered that while, generally, electrical losses are a measured quantity, frictional losses from the present system of drive are bound to be fairly high, probably 10 per cent. to 12 per cent., and are practically unmeasured quantities. One very strong feature of the scheme under consideration would

be Mr. Durtnall's arrangement for electrically operated winches, one of the smaller units in the engine room driving a dynamo for the purpose of cargo discharging. Essentially the fittest place for any power generation is the engine room, instead of the present system of ten or more scattered winches.

Sea water would be used for the scrubbers attached to the gas plant. Doubt has been expressed in certain quarters as to the use of sea water in the engine jackets. As, however, large volumes of water are circulated and are not allowed to boil, there is no reason to anticipate trouble in this direction.

Although, in view of the high efficiency of the electric motor of the present day, troubles are of rare occurrence with well-designed machines, provision ought to be made for even such a remote contingency as the "burn out" or "fusing" of the electric motor, and it is suggested that this should be accomplished by the addition to one propeller on an emergency shaft, the same being directly in line with one of the power units, so that, in the event of the tunnel becoming flooded, or the motor useless from other causes, the shaft could be brought into operation, and, current being off the dynamo or motor, slow speed could be maintained by the emergency shaft for some time through direct drive from the engine. Although this paper is on gas engines, it is hoped that serious objection will not be taken to the inclusion in the scheme of a small oil engine, which, as hitherto explained, performs a double purpose. As, frequently when a cargo boat is in port, and as would be the case probably with a gasboat, there are periods when light is desired for the use of the ship for which it would be obviously uneconomical to run one of smaller gas units. The oil engine under consideration will furnish about sixty 16-candle-power lamps with current for about 2½d. to 3d. per hour. This little question appears to have more in it than meets the eye, and it would be interesting to have figures as to the steam cost of similar lights for the same length of time. For the purpose of comparison the following table has been made:

SHIP IN PORT AND NO CARGO DISCHARGE.

SMALL OIL ENGINE (Campbell).	STEAM.
Sixty 16-c.p. lights for 12 hours.	Donkey boiler for 12 hours.
Consumption	Consumption
= 4 pints paraffin per hour at 5d. per gal.	= 1 ton coal.
= 2s. 6d.	= 15s.

This is, of course, a small item of saving, but it would be seen that, even where the present steamer is concerned and where constant steam is not kept, it would pay to install a small oil-driven set for the purpose of lighting.

As to the type of boat where gas engines could be employed as auxiliary method of propulsion, one is of the opinion that an installation of 400 to 500 B.H.P. gas-driven plant could be adapted to one of the modern large sailing vessels, in which case, of course, the use of one or two propellers would be recommended, and there is every reason for belief that such an arrangement would prove exceedingly economical. The engines could be stopped when full sail was available, and the voyage could be considerably accelerated when in the locality of no wind or very light winds. It is, of course, obvious that there would be a slight reduction of the cargo space available, and that also a skilled engineer would have to be carried, but the increased speed would doubtless prove an additional inducement to shippers who desired reasonable time voyages. With a boat of, say, 2,000 tons gross, 5 to 6 knots an hour under power alone should be feasible in moderate weather. Assuming engines were required for 18 days on a voyage to Australia, fuel consumption would be about, in sailing vessel with auxiliarly gas engines, the fuel consumption.

500 B.H.P.= 575 I.H.P. using 4½ cwt. anthracite per hour = 5 ton 8 cwt. per day.

18 days @ 5 ton 8 cwt. per day = total consumed 97 ton 4 cwt. 97 ton 4 cwt. @ £1 1s. per ton = £102 1s. 3d.

An average voyage time to Australia for sailing alone = 80 days. Sailing and auxiliary gas engines—1 week = 850 knots; 1 week = 630 knots; 4 days = 400 knots; giving an

estimated time saved = 10-12 days. While the advantage of using engines, avoiding towage charges, and in cases of emergency, is a factor that should go far to lower the insurance rate of the sailing vessel.

Gas Auxiliary.	Steam Auxiliary.
500 B.H.P.	500 I.H.P.
Fuel consumption = 5 tons, 8 cwt.	Fuel consumption = 10 tons, 16 cwt.
Labor = 2 men.	Labor = 4 men.

Cargo space occupied with gas = 50 per cent. less than steam plant.

The consumption of fuel will be 1 pound per B.H.P. per hour, a liberal allowance; but it is probable that it would not exceed 0.9 per B.H.P. per hour. At 1,200 B.H.P. this would mean a fuel consumption of 1,200 pounds, which is: 1,200 pounds = 10¾ hundredweights per hour. Compared with steam plant, which usually bases its power on an indicated formula, fuel consumption for 1,200 I.H.P. at the rate of 2 pounds per I.H.P., would be = 2,400 pounds = 21½ hundredweights per hour, which, however, is frequently exceeded, particularly if the fuel is of bad quality.

The comparative fuel consumption, gas and steam, is estimated to be as under:

Gas.	Steam.	Stand by Losses.
1,200 B.H.P.	1,200 I.H.P.	Steam,
Actual, 1,380 I.H.P.	Fuel consumption	20 per cent.
Fuel consumption	per day	Gas,
per day	= 25 tons, 16 cwt.	4 per cent.
= 12 tons, 18 cwt.	15s.	

For cargo discharge in a cargo boat the following is a basis of comparison:

Gas.*	Steam.	Stand-by Losses.
200 B.H.P.	200 B.H.P.	Steam,
Fuel consumption for	Fuel consumption for	20 per cent.
12 hours	12 hours	Gas,
= 1 ton, 1 cwt., 48 lbs.	= 5 tons, 7 cwt., 16 lbs.	4 per cent.

*Using electrical winches.

Referring to the cargo discharge consumption, the writer is of opinion that the majority of engineers are acquainted with the excessive fuel consumption of the average steam winch, which (on account of its very low efficiency, owing to

condensation losses, etc.) may probably be put at 5 pounds per H.P. per hour as not too high an estimate. Hence 10 days loading or discharge under gas and steam systems is shown to be as follows:

GAS.	STEAM.
Fuel consumption = 10 tons, 14 cwt.	Fuel consumption = 53 tons, 15 cwt.
Cost, £11 11s.	Cost, £43.

The cargo space economy of the gas-engined steamer may be compared with steam as undernoted:

GAS.	STEAM.
1,380 I.H.P.	1,200 I.H.P.
50 days' passage.	50 days' passage.
Coal space = 645 tons.	Coal space
Cargo space economy = 550 tons.	= 1,250 tons.

An estimated liberal allowance has been made for any contingencies arising from extra room being required for producers, engines, etc. Another element of gain on the side of the gas engine is in the time required for coaling. The estimated consumption of fuel for the gas system is, say, for a 50-day voyage of a cargo boat £677, and for steam on the same basis £950.

The writer is confident that a well-designed steamer fitted with gas could show a profit of £1,000 over and above the steamer per voyage, irrespective of less labor costs, coaling time saved, cargo discharging fuel economy. Over and above this profit it is probable that from £200 to £250 would be saved in minor charges, which could be written off against the extra cost of construction of the boat.

It is but natural that engineers who have had experience of the good work done by the steam engine, and look with suspicion upon a system which has only been fully tried on land, but the entry of the gas engine is inevitable, and it is only fair to ask marine engineers not to anticipate difficulties before they arise. If science or progress did not demand a trial of this form of motor, there is the economic force represented by the shipowner who, in an age of competition with low freights and badly paying ships, is compelled to look for a

cheaper type of prime mover in his steamers. This he can have in the gas-engined boat or the auxiliary sailing vessel. Apparently it is not so much a question of building as inducing owners to leave the beaten track and pay a fair price for such a vessel, but it is to be hoped that a good trial will soon be made to demonstrate all the advantages claimed for the gas engines; our German competitors have already commenced construction of three such boats. The results of the experimental boats fitted by Messrs. Thornycrofts, Crossleys, *Capitaine* and *Beardmore* are not fully available, and even were these available, might not afford much elucidation. However, the engines and plant recommended are recognized, tried, proved and satisfactory component parts of the scheme under consideration, and are not machines unknown or untried for reliability.—"Gas and Oil Power."

NOTES ON THE PROPOSED METHOD OF PROPULSION.

The opinions advanced are very optimistic as to the success of the combination proposed. But there does not seem to be in it any approach to the best reciprocating engine of today.

To begin with, it is proposed to use either anthracite coal or coke. A ready supply of neither is at hand at many prominent commercial points, and the price of anthracite coal is very much in excess of good steaming bituminous. A marine gas producer *successfully* using bituminous coal has yet not been produced. For these reasons the proposed system could only apply to craft employed in local work.

For the powers proposed for cargo boats the installation would be vastly more complicated than the present reciprocating practice, and the weight would no doubt be increased. The proposed speed of revolutions, 250 to 300 for a cargo boat, is somewhat high and the propeller efficiency would undoubtedly be low.

The assumption that a reciprocating engine of 12,000 I.H.P. will require 2 pounds of coal per horsepower is high, therefore poor design, but a good engine should only require 1.5 pounds per I.H.P. The assumption that the friction loss on

a reciprocating engine is equal to 10 to 12 per cent. is also off. This would probably vary from 3 to 8 per cent. in good design.

As to applying the system to naval vessels, the question of rapid and ready speed regulation is at hand. It is difficult to see how this necessary speed regulation and variation in power is to be obtained without great and objectionable complication. The great simplicity and absolute direct control of speed on a reciprocating engine are advantages somewhat difficult to secure by the combination proposed.—H. C. D.

Mr. McKechnie's Patent.—At the meetings of the Institution of Naval Architects, as reported in our columns at the time, Mr. James McKechnie, the managing director of Vickers' Sons & Maxim, Ltd., Naval Construction Works, Barrow-in-Furness, prophesied that the gas engine would soon be applied to drive large vessels. The "Steamship" understands that he has since then been carrying out elaborate experiments in this direction, and it is rumored that the British Admiralty are greatly interested in the subject. Mr. McKechnie has recently taken out a patent relating to internal-combustion engines, particularly to engines in which the combustible is derived from the spraying of a heavy oil. It consists in a construction of the cylinder head and valves which permit of the use of very large valves, and particularly of a very large exhaust valve; the engine may be run at a higher speed, thus reducing its weight and increasing its efficiency. The construction also admits of efficient cooling of the valves and cylinder head, and the form of the inlet and exhaust valves is such as to efficiently protect the valve springs, which are so placed outside the valve casing that they are practically not affected by the heat. The cylinder head consists of a hollow casting having openings for the exhaust valve and oil injector. The valve casings consist of hollow castings dome-shaped, having hollow cylindrical spigots, which form the valve seats. These spigots are arranged in conjunction with the hollow cylinder head in which they are fitted, with cooling-water circulation, and the exhaust-valve dome is made hollow, and the interior connected by ports with

water circulation of the cover. The exhaust valve and stem are also made hollow with a central tube leading the cooling water to the body of the valve whence it passes to the hollow stem from which it is discharged. Central tubes in the valve casings form guides for the valve stems, and are extended outwardly to guide the valve springs, which are compressed between follower plates on the ends of the valve stems, and shouldered abutments on the domed casings. The oil valve and spraying nozzle passes through the cylinder head in an inclined direction, so that, while placed out of center with respect to the cylinder to admit of the largest possible size of inlet and exhaust valves being fitted, the oil is admitted to the cylinder near the axis, and the inlet end is bent so as to be normal to the cylinder end.—"Gas and Oil Power."

The following article, while not dealing with the application of an oil motor for marine service, describes the service operation of an oil engine of the type which seems to have good prospects for being commercially applied for marine propulsion.

DIESEL ENGINE PLANT AT PHILADELPHIA GAS WORKS.*

The Diesel engine is an internal-combustion engine which utilizes as fuel crude petroleum or distillate without previous gasification. It has also been run successfully on water-gas tar, a by-product from the water-gas process of about 1.06 specific gravity and viscosity slightly more than ordinary fuel oil. The Diesel engine is essentially an oil engine, as compared with engines which burn distillate or crude oil by previously vaporizing it in an iron retort heated by the exhaust.

These latter engines are practically gas engines, and while they utilize distillate satisfactorily, a deposit of coke is left in the retort when using crude oil which must be cleaned out at rather frequent intervals. With the Diesel, however, there is

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*Paper read before the Engineers' Club of Philadelphia by John S. Haug.

no residue whatever, even from those fuels which contain suspended carbon, as does the water-gas tar before referred to. The exhaust is absolutely colorless. A sheet of white paper held over the exhaust will show no stain. This means that combustion is probably as nearly perfect as can be obtained.

The Diesel engine is distinctly a combustion engine as opposed to an explosion engine, in that there is little or no rise in pressure when the fuel is injected; in fact, what is aimed at is an isothermal combustion, which, of course, would fall below the constant-pressure line. It operates on the four-cycle plan, as follows:

The first stroke is the suction stroke, and fills the cylinder with air at atmospheric temperature and pressure. This is constant for all loads. The second stroke compresses this air into the very small clearance of 7 per cent. of the volume swept through by the piston. As a certain amount of cooling from the water jacket takes place the compression falls somewhat below the adiabatic (the equation being approximately $pv^{1.3} = K$), resulting in a pressure of 500 pounds per square inch, and a temperature of about 800 degrees Fahrenheit.

Just before the dead center the fuel valve starts to open and the fuel is injected in the form of a mist by air at a pressure of about 750 pounds per square inch. As the fuel valve is open only very slightly, this injection does not take place at once, but lasts for about 10 per cent. of the stroke, resulting in a steady combustion. The temperature at the end of the combustion is about 1,900 degrees Fahrenheit at full load, but remains more nearly constant at light loads. This temperature is considerably lower than the explosion temperature of gas engines.

After the closing of the fuel valve the gases expand on the working stroke, the temperature falling. The equation for the expansion curve approximates $pv^{1.3} = K$. Just before the end of the stroke the exhaust valve opens. The fourth stroke expels the burnt gases. Over three times as much air is furnished as is necessary to support combustion.

It will be seen that one of the distinctive features of the

engine is its high compression. A comparison of the full-load indicator diagrams of the Diesel engine with 7 per cent. clearance and a gas engine using illuminating gas with about 27 per cent. clearance shows a compression pressure of 70 pounds and an initial pressure of 260 pounds for the gas engine, as against 500 compression and 530 initial for the Diesel engine, and an expansion of the burnt gases to 3.7 volumes for the gas engine, as compared to 6.7 volumes for the Diesel engine. The mean effective pressures of the above cards are 66 pounds for the gas engine and 105 pounds for the Diesel engine. The reason this high compression can be obtained is that air alone is compressed. This makes preignition impossible and does away with igniters.

From this it will be seen that the Diesel engine has a considerably smaller cylinder volume than the gas engine of equal power and the same number of revolutions per minute. This reacts favorably on the design, compensating to a considerable extent for the stronger construction necessitated by the high range of pressures in the cylinder, so that in weight the Diesel engine compares favorably with other internal-combustion engines of the same speed and power. The weight, including fly-wheels, of the three-cylinder 16-inch by 24-inch American Diesel engine of 225 horsepower and 164 R.P.M., is 356 pounds per horsepower. The single-cylinder 16 by 24 engine of 75 horsepower and 164 R.P.M. weighs 573 pounds per horsepower. The smallest three-cylinder engine built by the American Diesel Engine Company is 12 by 18, of 120 horsepower at 220 R.P.M., and weighs 275 pounds per horsepower.

One would expect from an engine with such a high compression an unusually good economy, and the Diesel comes up to expectations in this respect. One of the tests published by the American Diesel Engine Company of a three-cylinder engine of 225 horsepower shows that at quarter load it consumed 15,100 B.T.U. per horsepower hour; at half, three-quarters and full load it consumed 9,590, 9,130 and 9,030 B.T.U., respectively; at about 16 per cent. overload it consumed 10,000 B.T.U. per horsepower hour. The full-load consump-

tion represents an absolute thermal efficiency of 28.1 per cent. All the above consumptions are based on the actual output in brake horsepower of the engine, and include the amount of heat expended in driving the compressor, which furnishes air for the injection of the fuel. At full load 840 B.T.U. per horsepower hour were expended in driving the compressor, making 8,190 B.T.U. in main engine.

One of the most attractive features of the Diesel engine is the manner in which this economy is maintained at low loads, since most plants operate on light loads for a greater part of the time than on loads near the capacity of the machine. There are no "stand-by" losses.

The Diesel engine is adapted for high as well as moderate speeds. An engine has been brought out by the Augsburg Works in Germany for marine work, of 300 horsepower at 400 R.P.M., weighing with all accessories 22,330 pounds, or about 74.5 pounds per horsepower. They also show the characteristic low-fuel consumption of the Diesel engine.

The fuel cost is, however, not the only cost of operation. The consumption of lubricating oil is also part of the expense of running. The American engine has an inclosed crank case with splash system of lubrication, and an oil of flash point of about 580 degrees is used. The consumption of this oil for a three-cylinder 225-horsepower engine is about six gallons per day of twenty-four hours. This is the consumption obtained in the new Diesel engine plant at Station B of the Philadelphia Gas Works.

One of the disadvantages of the enclosed-crank case is that the crank shaft has to be packed to prevent the escape of oil. It is not always possible to keep this tight, especially in the case of our single-cylinder engines, where the fluctuations of pressure in the crank case are rather violent, in spite of a two-inch vapor pipe which is supposed to relieve this pressure. The crank-case oil consumption of our single-cylinder (75-horsepower) engines at Station A of the Philadelphia Gas Works is about 2.5 gallons in twenty-four hours.

The item of repairs is also one of the expenses which must

be considered. This in the case of the latest three-cylinder engines will compare favorably with the repairs of a steam plant, including boilers and accessories. The repairs on the single-cylinder engine are higher, because the duty is more severe. A fact which is sometimes forgotten is that repairs on a machine that runs twenty-four hours a day will be over twice as much as those on a machine running ten or twelve hours a day.

The small attendance required is one of the strong points of an oil engine. It requires more care and attention to keep it in running condition than a steam engine does, but the boiler room, with its firemen, water tenders and handling of coal and ashes, is entirely eliminated, the net effect being a decreased attendance for the plant as a whole when compared with a steam plant. The average careful, intelligent steam engineer, with proper training, can run the Diesel engine successfully. In this point of attendance the oil engine also surpasses the gas engine, which must have a producer plant for economical operation in large sizes, if no cheap gas is obtainable.

As to reliability, the new plant at Station B, already referred to, has operated for several months successfully without interruption of service due to the engines. The plant consists of three 225-horsepower 16 by 24 three-cylinder engines of 160 R.P.M., direct connected to 25-cycle alternators, which operate in parallel. There are three three-stage air compressors, two of them motor-driven and the third steam-driven. These air compressors were built by the Norwalk Iron Works Company and have been very satisfactory. One steam-driven air compressor is a necessity in a plant of this kind, if only as a safeguard against accident.

The Diesel engine plant at Station A, Philadelphia Gas Works, consists of two 16 by 24 single-cylinder engines of 75 horsepower each at 160 R.P.M., belted to a Wilbraham Green gas exhauster. There are two two-stage single-acting air compressors built by the American Diesel Engine Company. One of them is belted to one of the engines. The other is belt-driven by a small steam engine. In both plants there are four

heavy steel bottles for each engine, 8 inches diameter by 4 feet long, to act as air reservoirs in starting, etc. One of the engines at Station A had the remarkably long run of forty-eight days and thirteen hours without shut-down. The engine was in good condition when shut down, with the exception of a leak from the fuel-valve packing. This shows what can be done in long runs. It is probably unwise to let an engine run so long, because of the desirability of regular inspection.

In general appearance the American Diesel engine resembles somewhat the ordinary vertical gas engine, as it is single-acting, vertical, with enclosed crank case, inlet, exhaust and jacket water piping. The valves are in the cylinder head in a projection on the side of the cylinder. The inlet, or air-admission valve, is carried in a cage bolted to the head and is vertically over the exhaust valve, the inlet valve opening downward, while the exhaust valve opens upward, both valves being cam-operated. Neither the inlet nor exhaust valves are water-cooled, but are plain bell valves made of nickel-steel and of about the same shape and size. The fuel valve, which consists of a 25 per cent, nickle-steel needle $\frac{5}{8}$ inch diameter and about 12 inches long, is carried with the atomizer horizontally in the needle-valve bracket, which is bolted to the side of the cylinder head. The needle valve is closed by a heavy spring and opened horizontally by the thrust of a bell crank operated by a cam. The spray of fuel is injected into the combustion chamber in the cylinder head, across the space between the faces of the inlet and exhaust valves. The starting valve is also carried in a small cage bolted to the cylinder head and is opened vertically upward by a cam.

The cam shaft, driven by spur gearing from the crank shaft at half the speed of the latter, runs in the crank case and carries four cams. The admission and exhaust cams are keyed solidly to the shaft, while the fuel and starting cams are mounted on a barrel driven by a feather key attached to the cam shaft by screws, allowing the barrel to be shifted along the shaft by a lever in such a way that when the lever is thrown one way the fuel cam alone engages its valve rod; and when the lever is

thrown the other way the starting cam alone engages its valve rod.

Starting the Engine.—In starting, the engine is placed slightly past its upper center on the working stroke, with the starting lever thrown over so the starting cam engages its valve. The starting valve will then be open. A charge of oil is then pumped up to the fuel valve by hand and the injection-air pressure turned on. When all is ready the stop valve on the compressed air line to the starting valve is opened and the engine starts off on its regular cycle, with the exception that on the working stroke a heavy charge of compressed air is let in instead of the regular fuel injection. After three working strokes—six revolutions—which are necessary to bring the engine to a high enough speed and temperature, the starting lever is thrown over to engage the fuel-valve rod with its cam, cutting out the starting valve, and a heavy charge of oil is ignited, the engine quickly coming up to speed. The fuel cam can be shifted slightly in a plane at right angles to the cam shaft to allow different settings of the valve for different oils. By lengthening the fuel-valve rod the needle valve can also be made to open earlier and close later, and by shortening it to open later and close earlier. Thus there are two different adjustments.

The valves are five in number. The admission, exhaust and fuel valves are used in the regular operation of the engine, and there are also a starting valve, actuated from the cam shaft, for starting the engine with compressed air, and a safety valve to relieve pressures above a certain point; roughly, in the neighborhood of 700 pounds per square inch. The seats of the valves are all in the head. The exhaust valve seat is in the head directly, while the other valve seats are in removable cages bolted to the head.

A distinctive feature is the process of the injection of fuel, which takes place through an atomizer constructed of two concentric tubes. The inner one fits the needle valve closely, and the space between the inner and outer tubes is filled with oil from a duct milled along the side. The compressed air centers

along another duct through holes into the annular space containing the oil, and blows out with the oil when the needle valve opens through another set of holes at the outlet end of the atomizer.

The governor is driven by a bevel gear and pinion from the end of the cam shaft. The fuel-pump plunger is driven by an eccentric sleeve on the end of the cam shaft, the sleeve being driven through a pin from the cam shaft. The method of governing is extremely simple and ingenious. The fuel-pump suction valve is opened by a lever pressing down on the suction valve as the plunger goes up, the other end of the lever being attached to the plunger. The suction valve is closed by a spring. The fulcrum of the suction-valve lever, which is between the plunger and the suction valve, is movable, and its position depends upon the position of the governor balls. Thus, when the balls have risen to their highest point, due to an increase in speed of the engine, the movable fulcrum is depressed so that the suction valve is held open for all positions of the plunger, consequently no oil is delivered to the engine. When the speed drops the fulcrum rises and permits the valve to close. As soon as the suction valve has closed, and not until then, oil is forced up to the needle valve. It will be seen then that the lower the speed is, the earlier in the stroke of the fuel-pump plunger does the suction valve seat itself, and as the speed increases the suction valve begins to seat itself later.

The revolutions per minute remain remarkably steady. Of course, the variations in angular velocity per cycle are considerable in a single-cylinder engine, but in the triple-cylinder engine are not large enough to prevent working alternators in parallel, which is done in the plant at Station B, Philadelphia Gas Works, already referred to.

The most serious cause of trouble in the Diesel engine, and in fact in any internal-combustion engine, is loss of compression. This affects the engine in two ways: first, by reducing the temperature at the highest point of compression; and, second, by failing to give back to the fly-wheel all of the work

absorbed from it on the compression stroke. The compression of air which is allowed to escape uselessly in leakage results, of course, in a direct loss of power, while the reduction of the temperature results in another loss, in that the combustion, which under proper working conditions should take place during the opening of the needle valve, is not completed until well after the valve is closed, causing a considerable loss of area in the upper part of the indicator diagram.

The immediate indication of the loss of compression is incomplete combustion, resulting in a smoky exhaust instead of a clear one. This necessitates increasing the pressure of the injection air, so that the fuel is injected in a state of finer subdivision. This will clear up the exhaust in all but the worst cases, but an extra load is thrown on the compressor and an increase in the oil consumption per unit of work is noticed. As the loss of compression goes on the load the engine will carry without smoking decreases, and the oil consumption increases.

One of the first things to learn in operating the engine is that it should never be allowed to run with a smoky exhaust. As soon as the condition of the engine becomes such that it will not perform the duty expected of it without smoking a thorough search should be made for the cause of the trouble. Perhaps the most frequent loss of compression is by leakage past the valves.

The exhaust valve is most frequently affected in this way, and it may be due to a poor seat, pitted by particles of carbon getting under the valve and forming depressions. The remedy for this is regrinding. This is done by putting oil and emery on the face of the valve and rotating it with a brace and special bit while pressing it down on its seat. Sometimes the seat of the valve appears good, but leakage takes place because the valve assumes another position when working from that in which it was ground. When this is the case the seat, instead of being clean all around, is bright on one side and dark on the other, the dark patch showing where the leakage has taken place. This is usually due to looseness in the exhaust-valve

guide, and the remedy for this is also regrinding more carefully. This looseness in the guide is often caused when grinding the valve by oil and emery running down the stem and getting into the guide. This can be prevented by wrapping a cloth around the throat of the valve above the guide.

An exhaust valve is occasionally found with a V-shaped portion of the seat burned out. This is due to overheating caused by a leaky needle valve. This condition exists by itself and also in conjunction with a cylinder head cracked in the exhaust-valve seat. The leakage of hot gases concentrated at one point soon produces a local temperature equal to the fusing point of the metals, with the result that both valve and seat are burnt. We have repaired such valves by welding a piece of soft steel into the damaged edge of the valve and remachining it. It is necessary to ream down the seat in the cylinder head, if it is damaged, until a good bearing all around is obtained. In case the cylinder head is cracked at that point a very good temporary repair can be made by drilling and tapping out the crack in the seat and plugging it. The remainder of the crack can be drilled with one-quarter-inch holes three-quarters of an inch apart to act as pouring gates for a cement composed of sal-ammoniac and iron borings. This should be allowed twelve hours to set. Cracks at this point in the cylinder head are usually caused by overheating from a leaky needle valve, but sometimes are due to a poor casting containing internal strains. We have permanently repaired a cracked head by rebushing the exhaust-valve seat with a cast-iron ring, and it seems to stand very well. A leaky needle valve will also cause the exhaust valve to dish, being deflected by the pressure while in an overheated state.

Trouble with the admission valve is less frequent, since it is kept relatively cool and clean by the entering air. It will occasionally foul, however, especially if the needle valve leaks, or if the engine is allowed to smoke.

Leakage past the admission valve is easy to detect, since it can always be heard, which is usually not the case with the exhaust valve. The admission-valve cage which contains the

admission valve is bolted to the cylinder head, an annealed copper gasket making the joint. Leakage past this gasket cannot be distinguished by sound from leakage past the admission valve, but the remedy is very simple.

Care should be taken that all valve rods are so adjusted that they do not prevent the valves from seating, as this trouble sometimes occurs when putting in new valves of perhaps slightly different lengths. A clearance between rod and valve of one-sixteenth of an inch is advisable, except in the case of the needle valve, where the clearance is smaller.

The exhaust and admission valves sometimes stick, due to fouling of the stems. Ordinary machine oil works very well in preventing this on the admission valve. Nothing but kerosene, however, should be used on the exhaust-valve stem on account of the danger of carbonization.

Leakage past other gaskets, except the safety-valve gasket, or leakage past the joint of the cylinder head, can be both heard and seen, especially when the engine smokes. The remedy in the case of the gaskets is obvious.

The cylinder head makes a ground joint one-half inch wide around the cylinder. If this leaks the best thing to do is to grind it in with flour of emery. We have tried copper gaskets and blow-hole cement, but neither gave satisfaction. The ground joint, with ordinary care, is absolutely tight. Sometimes the cylinder head leaks because it has not been bolted down tightly enough. The head of the 16 by 24 engine is held on by eight 2¼-inch nickel-steel studs. We proceed as follows in tightening down the heads of our engines, which are of the above size: The nuts are first tightened down by hand with a 3-foot wrench. Next a 9-foot wrench is used, three men pulling on it with a long rope, going around the head once and giving about the same pull on every nut. Then the head is heated by admitting water and steam into the jacket until a temperature of about 140 degrees Fahrenheit is obtained. It is allowed to remain at this temperature for at least one hour. This is necessary to allow the studs to become thoroughly heated.

After the studs have become well heated the 9-foot wrench is used again with four or five men going around until everything is tight. Twice around is usually sufficient after heating the head.

Cracks sometimes occur in the cylinder head which cause leakage into the jacket water. If the jacket water discharges into a funnel beside the engine, as it should be arranged to do, this leakage can be detected by an irregular flow of the water and discharge of air bubbles. A badly cracked cylinder head is probably fit only for the scrap heap.

Leakage past the gasket of the safety-valve cage goes into the jacket-water space, and can also be detected by an irregular discharge of the jacket water, accompanied by bubbles of air.

A loss of compression will sometimes be caused by the clearance between piston and head, increasing by wear from $\frac{3}{32}$ inch or $\frac{1}{8}$ inch, which is the proper clearance, to $\frac{1}{4}$ inch or more. The remedy is to lengthen the connecting rod by putting a shim $\frac{1}{8}$ inch thick or more between the connecting-rod body and upper crank-pin box.

We now come to the most serious leakage of all, which is the leakage past the piston. Aside from a cracked cylinder head, this leakage is the most serious, because the hardest to remedy. It is caused usually by defective lubrication, clogging of the rings by carbon, broken or badly-fitting rings and rings that are worn out.

Defective lubrication is easily remedied by keeping the necessary quantity of oil in the crank case.

Clogging of the rings by carbon is often partly due to lack of lubrication, but is mainly caused by letting the engine smoke. The particles of carbon are caught in the piston-ring grooves, and often rings become so firmly cemented in that they must be broken before they will come out. It is, of course, impossible to keep the engine from smoking once in a while from sudden and unexpected loads, but if the piston is kept well lubricated, these particles of carbon are not allowed to collect. Where the carbon has collected, if the carbonization is not in too advanced a stage a little kerosene poured on the piston and

allowed to penetrate the grooves for the rings will aid greatly in freeing them. If, however, the carbonization has proceeded so far that this treatment, repeated several times, a day or two apart, has no apparent effect, the only resource is to remove the head and lift out the piston. Where a ring is taken out which has been cemented in, it is generally better to make a new one to replace it, as, even if it is possible to remove it unbroken, the chances are that it is so sprung out of shape as to no longer fit the cylinder. Frequently when rings are thought to be carbonized they are found to be broken. This may be caused by faulty material or construction. Sometimes rings are found to be very little worn, but they no longer retain their elasticity and have taken a permanent set. This is a sign of poor material. In choosing a material for repairs of almost any kind the best is always the cheapest, especially where the labor cost is the larger part of the expense. Cast iron for piston rings should be hard and close grained, and should have a high elastic limit. In making a set of piston rings it always pays to jig them. When a ring is jigged it is first roughed out on the casting, allowing for finishing on the inside and outside. The ring is then cut off the casting, then cut and sprung together, and held there by pinning the ends, while a finishing cut is taken on the inside and outside. The result is that the ring when sprung to the size of the cylinder is truly circular. A ring that is turned to size on the piston casting and then cut and put on the piston will not fit the cylinder, no matter whether it is a straight or eccentric ring. Sometimes the cylinder is out of round, so a truly circular ring would not fit it. The ring should therefore always be fitted into the cylinder with red lead in the piston in which it is to run, and then pinned on the piston in that position.

It will be noticed that most of the trouble from loss of compression is caused by needle-valve leakage and allowing the engine to smoke. There are two ways of detecting needle-valve leakage; first, by a pound in the engine just before passing the top center, caused by the fuel leaking into the cylinder and igniting too soon; this is also an indication of a too early

opening of the needle valve. Another way is by undue heating of the exhaust pipe and that part of the cylinder body surrounding the exhaust valve. These are usually indications of bad leakage, however, and to effectually forestall any tendency of the valve to leak it should be tested periodically by pumping oil up to the valve against the injection-air pressure. By taking out the admission-valve cage the orifice of the needle valve is exposed, and any leakage can be immediately detected. If it leaks, it should be ground in. In grinding in a valve a narrow seat is the tightest one. In the case of the needle valve, which is five-eighths of an inch in diameter, a bearing one-thirty-second of an inch wide all around is the preferred one.

All fuel oil should be thoroughly screened through very fine wire gauze, since any impalpable, solid matter suspended in the oil will cause wear of the needle-valve seat, and consequent leakage.

Once every ten days is not too often to test the needle valve, and it should be made an opportunity for inspecting the engine generally. The exhaust and admission valves should be examined and reground if necessary. The crank case should be opened and the amount and condition of the oil noted. The level should be at about the center of the crank pin when on the bottom center, the oil consisting of a layer of about one-half inch thickness, the rest being water. Sometimes the oil is found in a thick, pasty condition, and looks something like raw liver. A couple of bars of yellow laundry soap thrown into the case will usually thin the oil up. This is sometimes caused by smoking of the engine.

All interior working parts should be inspected, and all bolts, nuts and cotter pins tested to make sure they are tight. The safety valve should also be examined to make sure it is free to move. The first heavy ignition in starting the engine, if the compression is good, should cause the safety valve to pop. If this does not happen, the valve should be examined at the next shut-down, and if apparently all right, the pressure of the spring should be decreased.

Sometimes the engine shows a lack of full power and the

exhaust is nevertheless clear. The trouble will then usually be found to be due to an insufficient supply of oil. This may be caused by the clogging of the supply pipe or leakage in the fuel pump. If there is no visible leak—*i.e.,* if the gaskets and plunger packing are tight, it is probably due to the suction valve becoming pitted. When such is the case it should be ground in.

In keying up the connecting rod of the engine great care should be taken to get both ends snug, yet with sufficient play to obviate heating. The reason the rod should be snug is that the clearance is only one-eighth or three-thirty-seconds of an inch between the piston and cylinder head, and while on the compression stroke the piston is jammed down and every bit of lost motion taken up, on the exhaust stroke this is not the case, and the piston is flung up with tremendous force—enough to lift the fly-wheel when the main bearings are slack.

A good way of telling whether the bearings are in free-running condition is to let the engine roll over from the top center. If the bearings are free the crank will pass the bottom center by about 45 degrees and then settle back to the bottom center. If they are too tight the engine will not pass the bottom center at all, or, if it does, will stick where it stops. This only applies to the single-cylinder engine, however.

We have had some trouble with the air compressors in the past. We would grind in the valves and find them a few days later caked with dirt and rust and the seats showing signs of corrosion. That trouble was entirely obviated by the use of one-quarter pint of soapy water in the low-pressure lubricator three times a day. Now we find the seats with a mirror-like polish and clean valves.

That may be accounted for in the following way. It is well known that iron does not oxidize rapidly except in the presence of carbon dioxide and moisture. The carbon dioxide in the compressed air, dissolved in the moisture condensed out of the compressed air in the intercooler, and thus formed weak carbonic acid, which, in company with the oxygen of the air, created excessive oxidation. The alkali in the soap was suffi-

cient to neutralize this carbonic acid, and consequently the oxidation did not occur.

After about nine months of continuous running the rings in the high-pressure cylinder are usually worn out and the piston one-thirty-second of an inch loose in the cylinder. We then have the cylinder rebored, specifying a new steel piston, ground to fit cylinder, and a set of 8 cast-iron rings also to fit cylinder. We have put cylinders into commission repaired in this manner which for some time had no perceptible leak past the piston, although compressing up to from 750 to 1,000 pounds per square inch.

Another very practical and well-considered discussion of the matter which treats of the subject from present data and actual performance rather than from optimistic hopes or flights of enthusiasm is the following:

THE PROPULSION OF SHIPS BY INTERNAL-COMBUSTION ENGINES.*

As the problems connected with the propulsion of ships by means of internal-combustion engines are daily coming more to the front, it may be of interest to relate briefly what has been accomplished up to the present in this direction. The chief reasons why this form of propulsion commends itself are (1) the absence of boilers, casings, funnels,† etc., and (2) the economy effected in fuel consumption. The reduction of machinery space is specially marked with oil engines. Other advantages will be referred to later.

The development of the marine internal-combustion engine has been somewhat slow, but its general adoption appears now to be only a question of time. The fuel used is either gas or oil, depending mainly upon where the vessel is intended to trade

*By F. Dekeyser, C. E., in the "Ship Builder." Republished in the "Marine Review."

†This advantage, absence of funnels, etc., will, however, be offset by the arrangements for conducting the waste gases overboard, by a powerful installation, say twenty or thirty thousand I.H.P. These arrangements may result in more troubles and difficulties than do the funnels of the steam boilers.

and upon the price at which the fuel is obtainable. In Great Britain gas enginees appear to be preferred, owing to the abundance of coal from which the gas is generated. In other countries, notably in Russia, oil engines are more favored, since cheap and plentiful supplies of petroleum are available. Internal-combustion engines may be either single or double acting, and of the two or four-stroke type, according to whether the explosions occur every second or fourth stroke.

First, let us deal briefly with the generation of fuel in gas engines. For moderate powers, the generating plant is frequently of the suction type, in which case gas is drawn from it a little under atmospheric pressure. In other types gas is delivered to the engines under compression. The former system seems preferable for marine purposes, since there is no danger of leakage. Various types of gas producer have been devised, the chief differences arising from the kind of coal (anthracite or bituminous) to be used.

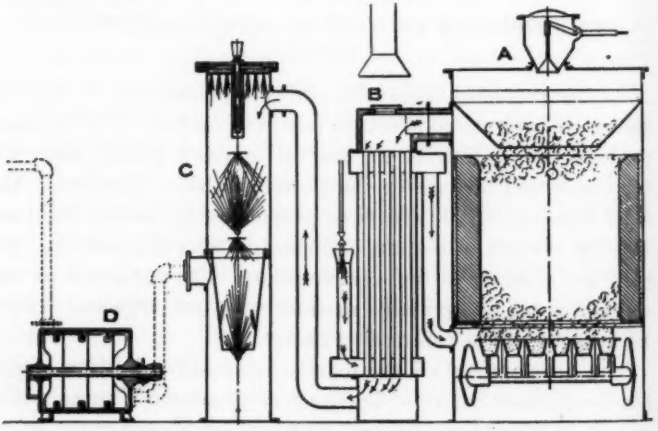


Fig. 1.—"CAPITAINE" SUCTION-GAS PLANT.

For the purpose of illustration we have selected the "Capitaine" suction-gas plant. The installation shown in Fig. 1 consists of a cylindrical shell (A) lined with firebricks and having a feed hopper on top, steam and air for generating

purposes being supplied from below. The gas first passes through a cooling vessel (B), next through a cleanser (C), where all particles of dust and impurities are mixed with a fine spray of water, and then the gas is purified by passing through a centrifugal apparatus (D). This plant is specially designed for anthracite, from which a comparatively pure gas is obtained. When bituminous coal is used, however, tar and other by-products are obtained, which obstruct the engine valves. In this case the gases, after being generated may have to pass first over the lower and hottest parts of the generator in order to decompose these by-products, as in the Duff-Whitfield producer. In other systems the coal is supplied from below direct to the hottest parts so as to decompose the tar at once, as in the Boutillier suction plant. Other means for cleansing the gas have also been adopted.

Coming now to the marine gas engine, among the pioneers of this form of propelling power may be mentioned Messrs. John I. Thornycroft & Co., William Beardmore & Co., Vickers, Sons and Maxim, and Mr. Vennel-Coster. The British patents connected with the "Capitaine" type of engine are owned by the two first-named firms. The 500 horsepower gas engine built by Messrs. Beardmore for H. M. S. *Rattler,* which has been running now for about twelve months and has given every satisfaction. It is five-cylinder, single-acting, four-stroke engine of 130 revolutions per minute and 24-inch stroke. The cylinders are 20 inches in diameter, which is about the largest size considered safe with non-cooled pistons. The inlet and outlet of gases are operated by means of cam shafts, placed on each side of the cylinders, the valves being operated by means of rocking levers. The framing is entirely built up with plates and angle bars.

One of the greatest difficulties to be overcome in connection with internal-combustion marine engines is the starting and reversing of the engines. In the *Rattler,* starting is effected by means of compressed air or gas, admitted through a special set of valves, in order to impart to the engines the first few revolutions. When reversing the engine, the shaft is first un-

coupled and the cam shaft is acted upon so as to bring the cams into the right position for making the engine run in the opposite direction. Compressed air is admitted again for the first revolutions, and the shaft is recoupled to the engine by means of a hydraulic clutch. There are two systems of ignition, viz: one of the low-tension magneto type and another of the high-tension lodge system. Forced lubrication is used for all bearing, etc. Gas is supplied by a producer plant of the same type as illustrated in Fig. 1, but with slight modifications and improvements in details. It may be added that Messrs. Beardmore have built another similar engine of 1,000 H.P., but double acting and having water-cooled pistons. If size permits, however, a single-acting engine seems preferable,

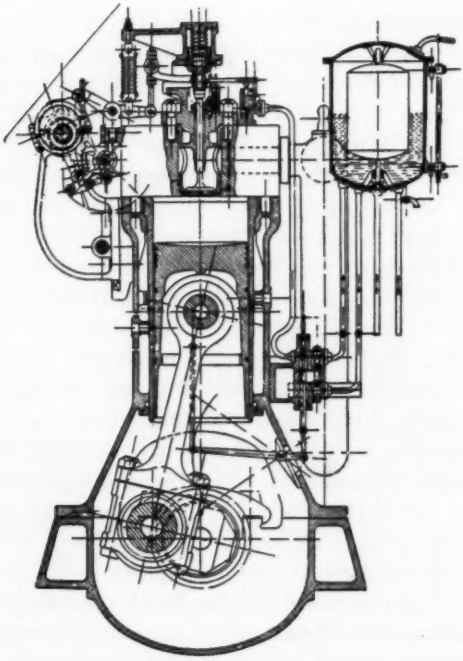


Fig. 4.—VOGT MARINE GAS OR OIL ENGINE.

on account of its simple construction, easier access for cleaning, and the non-cooling of the pistons, water-cooled pistons adding considerably to the first cost.

Fig. 4 illustrates a Vogt marine gas or oil engine as built by Messrs. Vickers, Sons and Maxim. As is well known, this firm has had extensive experience in this type of prime mover, most of the submarines built by them for the British Government having been fitted with internal-combustion engines; and their engineering manager, James McKechnie, has already made a proposal to fit a battleship with such engines. The engine illustrated in Fig. 4 is of the single-acting, reversible, two-stroke type; and it is claimed for it that it can be worked by either gas or oil, the change from one method of working to the other being effected very simply and almost instantaneously.

Mr. Vennel-Coster, of Manchester, has also built comparatively large sets of marine gas engines, but working on the Otto cycle (four-stroke type). Generally speaking, all these systems have given equally satisfactory results, and it is, therefore, difficult to say which offers the greatest advantages.

In regard to oil engines, we will only consider the Thornycroft and Diesel motors. The former has been fitted in a great many small craft, and may be considered as one of the best types of marine motors built in this country. Fig. 7 represents a set of engines just fitted by Messrs. Thornycroft in the triple-screw yacht *Bronzewing,* 120 feet long by 17 feet 6 inches beam. The machinery consists of three sets of 100-B.H.P. kerosene motors, having four cylinders each of 8-inch diameter and 8-inch stroke, making 750 revolutions per minute. Lubrication is forced to all bearings. The starting is effected by compressed air, supplied by a 6-B.H.P. motor and compressor, and reversing is accomplished by means of clutches, which make the whole plant as easily controlled as a steam engine. Reduced speed is obtained by leaving out either the center or both wing motors.

The Diesel motor, which has been specially developed on the Continent, and up to the present appears perhaps the best

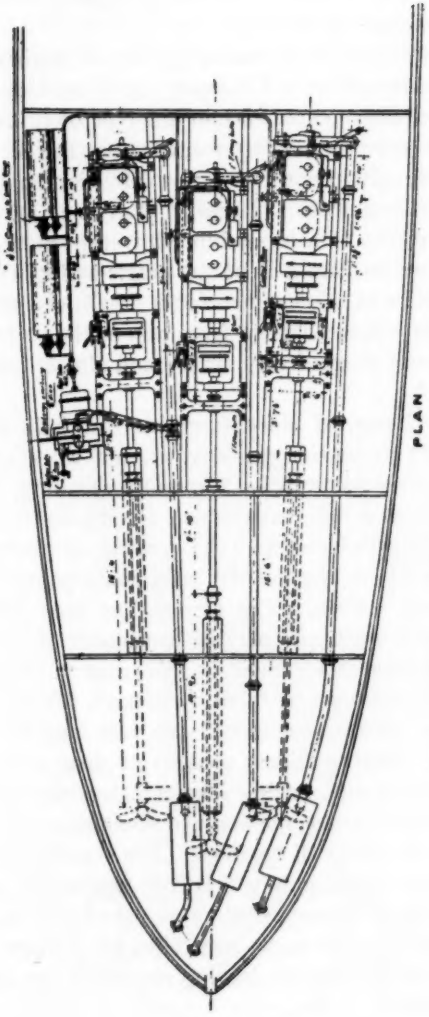
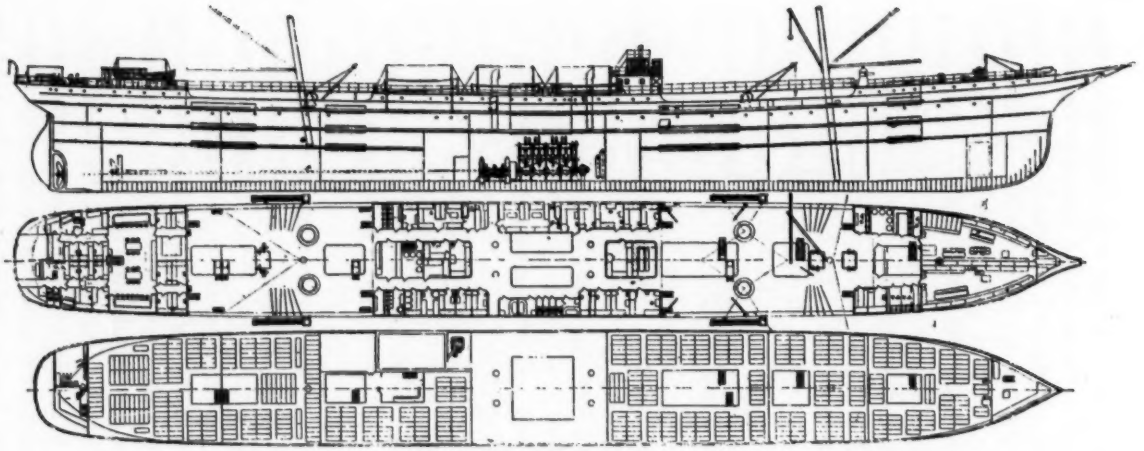


Fig. 7.—General Arrangement of Machinery in the Triple-Screw Yacht "Bronzewing."

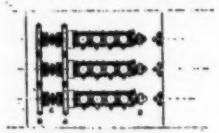
adapted for marine purposes on a large scale, is a single-acting, four-stroke, non-reversible marine engine, and therefore leaves room for improvement in regard to reversibility. In the first applications the difficulty was overcome by driving the shafts with electric motors. The next step was to drive the shafts directly from the main engines for ahead motion. When going astern an electric motor is thrown into action, requiring only half the power of the main engines, so that it may be overloaded 100 per cent. without inconvenience for short periods only. The connections to the shafts are obtained by means of a Del Proposto magnetic clutch. This system has been applied to the propulsion of barges on the Rhine, and also in Russia for petroleum tank steamers up to 245 feet long; requiring two 180-B.H.P. motors for a speed of 10 knots, the total weight of machinery being about 352 pounds per I.H.P. Several French submarines are fitted with Diesel motors, and they are also in use in the Germany Navy. Professor Boklewsky, of St. Petersburg, has made a proposal for a triple-screw passenger steamer 240 feet long, to be propelled by Diesel-Del Proposto machinery, and specially adapted for the trade between Odessa and Vladivostock. This design is illustrated in Fig. 9, which is reproduced from a pamphlet by Mr. A. Lecointe, of Brussels. Provision has been made for 600 tons of oil fuel, which is assumed amply sufficient for a return journey, say 20,000 miles, at a speed of 10 knots. Professor Koklewsky has prepared an estimate of the yearly saving in running a steamer propelled by this method as compared with the vessels now running on the line, assuming both to be fully occupied all the year round. He reckons that, owing to dispensing with firemen, reduced fuel consumption, and increased cargo capacity and passenger accommodation, the annual gross earnings should be increased by 25 per cent., which would mean an increase of 8 per cent. on the capital involved.

It should be added that the development of the Diesel engine has been retarded to a certain extent by commercial considerations; but as the patents will expire in the near future, more attention will doubtless be devoted to making this type re-



PARTICULARS OF HULL.

Length B.P.	420' 0"
Breadth	49' 6"
Depth to Upper Deck	32' 0"
Load Draught aft	24' 6"
Load Displacement	10,750 tons.
Carrying Capacity	5,250 "
Net Registered Tonnage	2,240 "



A = Dynamo.
B = Electric Motor.
C = Magnetic Coupling.
D = Small dynamo for do.

PARTICULARS OF ENGINES.

Number of Cylinders (for each set)	4
Diameter " do.	27½"
Stroke	30"
Number of Revolutions	150
Power of each Set of Engines	1,000 E.H.P.
Weight do. do.	110 tons.
Power of each Dynamo and Electric Motor	670 H.P.
Total Weight of Machinery, including Shaft and Propeller	564 tons.

Fig. 9.—PROPOSED 420-FOOT PASSENGER STEAMER WITH DIESEL-DEL PROPOSTO MACHINERY.

versible and double acting, and consequently more suitable for marine purposes on a large scale. Internal-combustion engines are now being extensively fitted in yachts. Lloyd's latest returns include 650 oil or petroleum-propelled yachts for British and 1,400 for American registry.

With further reference to the advantages of internal-combustion engines, the following figures give an idea of the economy in fuel consumption as compared with that of steam engines. For plants of 500 H.P. and upwards, steam engines consume say 1.60 pounds of coal per I.H.P. per hour, while gas engines require only 0.8 pound and oil engines (petroleum) 0.4 pound. At lower powers the difference between the consumption of steam and internal-combustion engines is still more marked. The comparative cost of running gas and oil engines depends mainly, of course, on the price of the two kinds of fuel, the absence of generating plant and the easier stowage of oil fuel being in favor of oil engines.

The disadvantages attending the adoption of the new form of ship propulsion may be tabulated as follows:

(1) Want of reliable data for high-powered engines, and complication of design when double acting is resorted to.

(2) Elaborate process for starting and reversing, and want of flexibility in the latter quality. This has been overcome in the Diesel-Del Proposto system, but at the cost of additional electrical plant.

(3) Great number of cylinders required for high powers, especially at the present stage. On the other hand, the number of cylinders reduces the inconvenience when one of them is thrown out of action, as it may be disconnected and examined without interfering with the others.

(4) Comparatively high cost of oil.

(5) Possible troubles with igniters, miss-firing, back-firing, premature-firing, etc.

These difficulties, however, are gradually being overcome with increased experience, and in the near future it may reasonably be expected that they will largely disappear.

THE OPERATION AND MANAGEMENT OF THE PARSONS MARINE STEAM TURBINE AS PRACTICED ON THE U. S. S. *CHESTER*.

By Lieutenant A. F. H. Yates, U. S. N., Member.

The writer's experience with turbine engineering has extended over a period of little more than four months in the shops and slightly more than one year at sea. It has been confined mainly to experience with the turbines of the U. S. S. *Chester*. In view of these facts, I can hardly presume to discuss in all completeness such a broad subject as the head lines cover. At the time I began my experience with the turbine, however, I searched in vain for literature of this nature and can safely say that none exists. I trust that my remarks will prove interesting and of value particularly to those who for the first time become associated with the practical operation of the turbine, and if such be the case I shall feel amply rewarded, as my efforts are directed primarily to that end.

The turbine installation on the *Chester* is of the standard type designed by the Parsons Marine Steam Turbine Company and differs to no marked degree from the latest systems now under construction. A brief description should suffice.

There are six ahead turbines, a high-pressure cruising, intermediate-pressure cruising, two main high pressures, and two low pressures. There are four independent shafts, each one fitted with a single, solid, three-bladed propeller of six feet diameter and six feet pitch. Reversing turbines are incorporated into the exhaust ends of each of the low-pressure turbines. A reference to Fig. 1, will make clear the arrangement of turbines on shafts and the piping leads. A complete description of the *Chester's* machinery will be found in Volume XX, No. 2, of the Society's Journal. The high vacuum main-

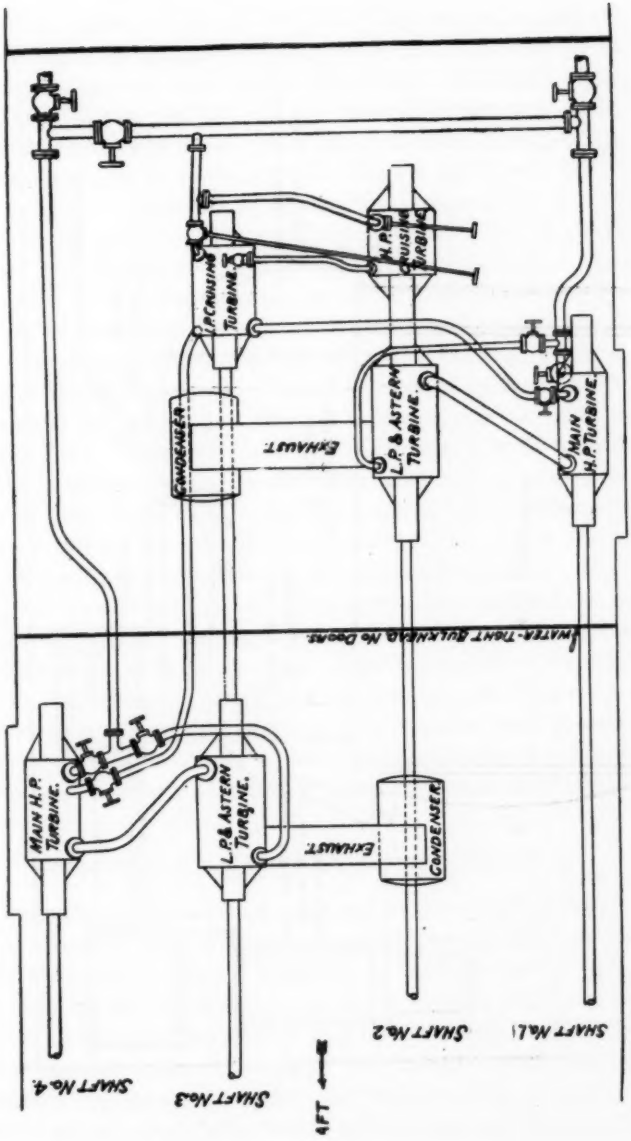

WATER-TIGHT BULKHEAD No. Doors.
MAIN H.P. TURBINE.
L.P. & ASTERN TURBINE.
EXHAUST
CONDENSER
H.P. CRUISING TURBINE
L.P. & ASTERN TURBINE.
EXHAUST
CONDENSER
MAIN H.P. TURBINE
SHAFT No. 4
SHAFT No. 3
SHAFT No. 2
SHAFT No. 1
1 FT

FIGURE 1

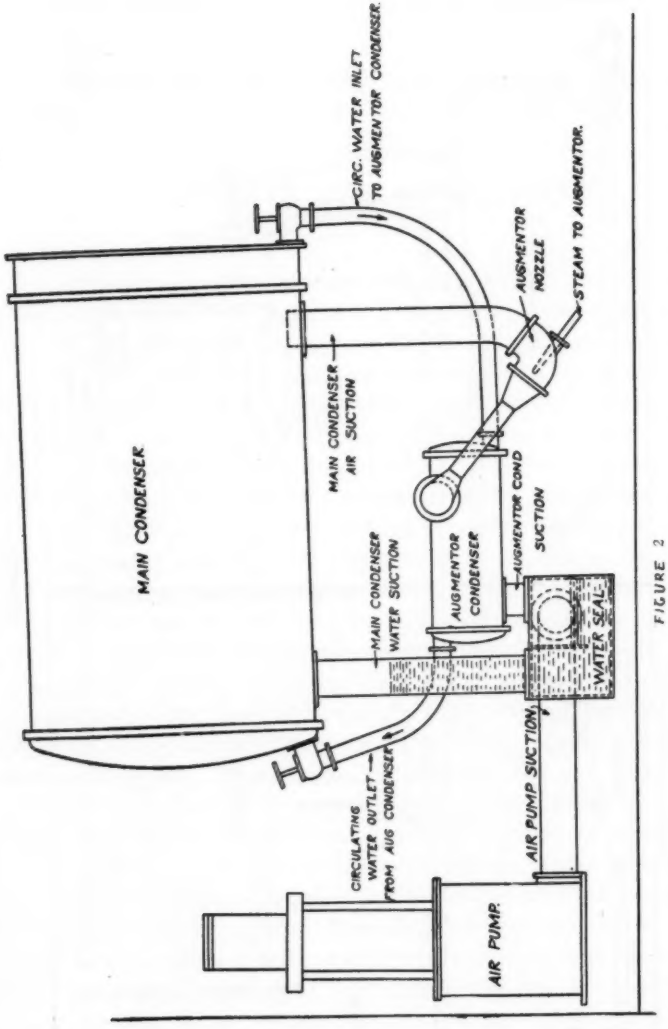

CIRC. WATER INLET TO AUGMENTOR CONDENSER.
STEAM TO AUGMENTOR.
AUGMENTOR NOZZLE
MAIN CONDENSER AIR SUCTION
MAIN CONDENSER
AUGMENTOR COND SUCTION
AUGMENTOR CONDENSER
MAIN CONDENSER WATER SUCTION
WATER SEAL
AIR PUMP SUCTION
CIRCULATING WATER OUTLET FROM AUG CONDENSER
AIR PUMP

FIGURE 2

tained is assisted by the use of the Parsons vacuum augmenter. Independent air pumps are installed with connections to the condensers through water seals. Reference is invited to Figure 2. The vacuum augmenters are virtually steam jets so arranged as to siphon the air from the condensers at a point just above the water level and deliver it to the water seal for the air pumps to handle, at a pressure of from one to one and three-tenths inches of mercury higher than the condenser pressure. The discharge from the siphon passes through a small condenser for condensation and reduction in temperature. The system of lubrication installed provides for the supply of oil to thrust bearings, main bearings and spring bearings at a pressure of about ten pounds. The oil is supplied by steam-driven oil pumps and passes first through coolers on its way into the supply main. Separate pipes from the main pipe to the different bearings conduct the oil to the latter and separate pipes take it away by gravity to common return mains which discharge into the oil tanks in the bottom of the engine rooms. It is from these tanks that the oil pumps take suction. There are no valves in the system. The pipes which conduct the oil from the bearings have sight glasses in them so that the flow of oil may at all times be under observation, and at the same points thermometers are attached to indicate the temperature of the oil as it leaves the bearings. At one time small pressure gauges were fitted at each bearing to indicate the oil pressure, but these gauges are of doubtful value if the other methods are in use.

WARMING THE TURBINES FOR GETTING UNDERWAY.

The utmost care must be exercised at this operation as successful management depends more on it possibly than on any one other point. Much is heard about "blade stripping" in the Parsons turbine, its liklihood to occur, etc. It might be expected to happen if an attempt is made to run the turbines before they have been thoroughly and evenly heated, though probably the tips of the blades only would suffer. Except for this cause, or some such remote cause as a large bolt or nut

finding its way into the turbine, stripping should never be expected in a properly constructed and well balanced turbine. Thorough and even heating, however, is imperative, and no pains should be spared to see it done.

The length of time necessary to properly prepare the turbine for trial is greater than for the reciprocating engine. With care and practice it can, however, be reduced to a minimum so as not to compare unfavorably with the reciprocating engine. The safest practice is to allow plenty of time except in emergencies and to avoid any unnecessary competition. No definite period can be stated here, as it depends on the size and shape of the turbine and the facilities for uniform heating. Three hours and a half are usually allowed on the *Chester* from the time of beginning to warm up to the time of getting underway, though the turbines are generally tried and reported ready after three hours. They have been made ready in tweenty-four minutes, and it is believed that they could be prepared in ten minutes. This, when it is considered that the *Chester's* brake horsepower is in the neighborhood of 24,000, cannot be considered unreasonable. That which is to be avoided is local heating and consequent uneven expansion. An examination of the turbine shows that steam is admitted to a circular steam belt, and in consequence the steam takes its initial direction over all parts of the rotor drum at the same time, and toward the exhaust end. At the exhaust end the steam leaves the turbine at the one point on the side of the casing where the exhaust pipe is connected. For this reason it might be expected that the near side would benefit by steam of perhaps somewhat higher temperature than that on the far side; that is to say, at this end of the turbine. In order to counteract any ill effects which might result from such cause it is considered advisable to utilize the jacking gear while warming up, turning the shafts one-quarter or one-half a cycle every half hour. In order, too, that the greatest possible benefit may be derived from the heat of the steam, it is considered a wise practice to keep an extremely low vacuum, moving the air pumps as slowly as possible with safety. The various exposed parts of the turbine not covered by lagging should be felt with the hand from

time to time, as much can be learned in this way as to the uniformity of heating. The use of auxiliary exhaust steam for warming up was at one time considered, but the idea was abandoned. On the *Chester,* connections from the auxiliary exhaust line are made to the second expansion of each main high-pressure turbine and into each low-pressure receiver pipe. On one occasion before the vessel was commissioned auxiliary exhaust steam was admitted to the port main high pressure in connection with warming it up, and the results were slightly disastrous, it being found when the turbine was tried that blades were rubbing in the second expansion. The casing was lifted later and an examination showed a few blades loosened and some bent on their tips, though the situation was not serious. This was caused by the unequal heating of this part of the turbine. In this connection, steam should be placed on the glands at the same time it is admitted to the turbines.

The general procedure of warming up the turbines on the *Chester* is as follows:

1. Open the drains of all turbines to the condensers and unseat all throttle valves and spring-loaded non-return valves.

2. Open main injection valves and overboard delivery valves. Start main air and circulating pumps, having circulating connections open to the vacuum augmenter condensers.

3. Crack the cross-connection valve in the communicating pipe between the auxiliary steam line and the main steam line in engine room, thereby putting steam on so much of the main steam line as is in the engine rooms. (This is done as the main steam line in fireroom spaces is quite extensive, and so much of it as is forward of the engine-room bulkhead stop valves is warmed up with the additional boilers to be used as steam is raised on them. This leaves the boiler in use for auxiliary purposes sufficiently powerful to warm the turbines without assistance.)

4. Close turbine throttle valves and open throttle by-pass valves. Keep a low vacuum.

5. Regulate pressure on auxiliary exhaust line, opening its connection to the steam-gland system sufficiently to give a pressure on the glands of about one pound.

6. Examine the strainers on oil pumps and test both pumps. Note first the amount and condition of oil in the gravity-return tanks; draw off any water that may be in the tank. See that water service is on the oil cooler and on the water jackets of the spring bearings.

7. Steam having been raised on the additional boilers to be put in use, connect them, and open the engine-room bulkhead stop valves, closing the cross-connecting valve between the main and the auxiliary steam lines. Close throttle by-pass valves, if desired, and continue warming up through the throttle valves partially unseated.

8. The turbines being warm, a set of micrometer readings for dummy clearances should be taken and entered in the log.

9. Open valves admitting steam to the vacuum augmenters. Disconnect jacking gear.

10. Start oil pumps, by-passing the oil around the cooler. It should continue to be by-passed until the ship is underway and the oil has reached a temperature of 100 degrees Fahrenheit, otherwise it will be sluggish and fill the bearings with difficulty.

11. Speed up the air and circulating pumps and raise the vacuum, and when a good vacuum has been obtained report the turbines ready for trial. Keep all drains open until well underway. When lying at anchor with banked fires and with orders to keep the turbines warm they should be jacked over at least once an hour. They remain warm a long time after securing, but steam should be kept on them. Fifteen minutes' notice is then considered sufficient.

TRYING THE TURBINES.

The turbines are tried separately at a low speed under light pressure, and if properly warmed they will move easily, and the chances of their giving trouble when opened out are none. In trying them 'ahead slow' sufficient pressure should really be given the main high-pressure turbine to insure the turning of its accompanying low-pressure turbine by the exhaust

of the former. This will not happen if the exhaust pressure is extremely low. On the *Chester* this is rarely done, as it results in giving the ship more motion than is desirable. The low-pressure turbines have never given trouble as a result. The test of the backing turbines is frequently repeated several times, it being the case very often that a rather high pressure is needed to turn them the first time. The cruising turbines should, of course, be tried out, but this, too, is omitted on the *Chester,* as it gives the ship too much motion. These turbines are so much smaller than the others that they are almost certain to be warm if the others are, and no difficulty has ever been experienced with them. If there is any interference of the blading in any turbine it will make itself evident by an intermittent rumbling or grinding noise which, if very serious, will be very shrill. The ears should be strained when the turbines are first tried in order to detect even the slightest noise, as a slight interference at such slow speed might increase and give trouble upon opening out the turbine. The internal noises of the turbine become magnified upon having placed the ear to one of the turbine-casing guide rods or by touching it lightly with the fore finger. (The guide rods referred to are standards fitted vertically at each corner of each turbine casing to assist in guiding the upper casing fair when it is being lifted, thus guarding against the blades of the casing engaging those of the spindle.) A pencil may also be held lightly against a guide rod or against some exposed part of the casing proper, and any interference inside can be detected by the resultant vibration. If at any time there is a reasonable doubt as to conditions the turbine should be stopped promptly and given more time to warm up. No more than fifteen or twenty minutes are apt to be lost by so doing.

MANEUVERING, STOPPING AND STARTING.

The turbines having been reported ready for use, signals from the bridge may be responded to with promptitude and dispatch. Maneuvering is accomplished with much greater

ease than with the reciprocating engine, as there is no reversing gear necessary to operate or to fail of operation. The operation consists simply of the opening and closing of valves, and consequently but very few seconds are ever necessary. The mistaken idea held by some who are not familiar with the turbine, to the effect that maneuvering is a lengthy operation, is entirely without foundation. An example which I will cite should clear away any beliefs to the contrary. During the first fifty minutes that the *Chester* was underway after going into commission, eighty-five signals were received from the bridge and each one was responded to. This was accomplished with a green crew, none of whom, including officers, had ever handled a turbine, and only three or four had ever seen one handled. The record was kept by a yeoman under my own personal direction and supervision, so I can vouch for each signal.

Full steam pressure may be admitted to the turbine as fast as the throttle can be opened, and the time occasioned to full open is but a few seconds. The valves should, most naturally, not be spun open with lightning speed, neither should they be opened irregularly by jerks. The turbines could hardly be expected to stand such treatment, but the valves may with perfect safety be opened smartly and with precision, and a sluggish response to a signal is entirely unnecessary. During periods of rest it is a good idea to admit an occasional blast of steam into the astern turbines for the purpose of keeping them warm. They act more efficiently when warmed up thoroughly, and the admission of light blasts of steam can be accompanied without turning the shafts. It can do no harm, even if an ahead signal is responded to at the time a blast of steam is passing in and before it is stopped. Due to the fact that the astern turbines are on the same spindle as the low-pressure ahead turbines, the dummy strips on the former must be of the radial type, whereas the latter are of the contact type. Figure 3 illustrates the two types. The latter type permits of close and comparatively uniform regulation of the clearance, as will be explained later. The former type is a permanent adjustment and cannot be as efficient, as it must permit of more

elastic limits. But one of the two dummies can have the type suited to adjustment, and it is, of course, most important that the ahead turbine should be the one so fitted. It is because of the type of dummy strips fitted in the astern turbines that more careful handling of these turbines is considered necessary. injudicious handling of the astern turbine throttle valves is particularly to be avoided. The same degree of attention is paid to one throttle valve as to the other on the *Chester*, and no trouble has ever been experienced with the astern turbines from such cause. Indeed no trouble from any source has ever been had. No more time is necessary in handling the astern turbine than any other.

FIG. III.

If a reverse signal is received from full ahead to full astern no anxiety need ever be felt. The valve to the astern turbine may even be started open while the ahead throttle is being closed, and, as the combined act required so little time, the reversal may be considered as almost instantaneous. Such an operation requires careful judgment, and should not be attempted until the operators are thoroughly experienced and acquainted with the installation. The men assigned to stations at the throttle valves should be carefully selected, and be men of fair intelligence and sound judgment. A marked feature of the turbine lies in the fact that, while less labor is required in connection with it as compared with a reciprocating engine, more skill is required, for it is a much more delicate apparatus.

If running under cruising turbines and a reverse signal is received the execution of the signal involves no greater delay. Indeed even less care is necessary than if the ship were running ahead under the main high-pressure turbines. This is because

spring-loaded non-return valves are fitted in the exhaust pipes between the intermediate-pressure cruising turbine and each of the main high-pressure turbines. Steam is promptly cut off the cruising turbines and at the same time the astern turbines' throttles are opened. Delay in attending to the former would cause no embarrassment, however, because of the valves above mentioned, which close automatically. In actual practice the non-return valve is usually closed by hand at the same time the remainder of the operation is being attended to. This should clear up any doubt as to occasion for accident due to the number of turbines in operation. The general practice on the *Chester* is to confine operations to the main turbines only, and allow the cruising turbines to revolve idly in a vacuum. It seems simpler, and that is considered sufficient reason. The cruising turbines are for economy at low speeds, and it might be thought that when maneuvering slowly the main turbines would prove wasteful, but the difference in economy is so slight that an hour or two of maneuvering would involve scarcely any appreciable loss.

Water in the turbines due to condensation or a result of priming need cause no apprehension. The drains are always open when maneuvering, and if the presence of water becomes known it disappears almost as quickly as it comes. It is broken into small particles and passes out with the exhaust steam in the form of spray, causing no damage. As the *Chester's* boilers furnish very dry steam this has seldom occurred in her turbines. On one occasion it was noticed in the starboard low-pressure turbine, an intermittent thump and pounding noise being heard for a few seconds, during which time the shaft slackened in its speed in jerks. The water cleared away without necessitating any action.

The inability of the turbine ship to compete with the ship fitted with reciprocating engines is a frequent argument against the adoption of turbines. The *Chester* receives her share of this criticism, and a great part of it is based on misunderstanding of conditions. All of her backing power is contained in two astern turbines, as previously mentioned. These turbines

are of high power design and are in general uneconomical, this being partly due to their being of stunted dimensions with short blades and partly due to the inefficient type of dummy strips which must be employed. For this reason high pressures of steam are most necessary to insure successful results, but most important is the necessity for having a sufficient supply. Therein lies the difficulty in nearly every instance where backing is not entirely satisfactory. Usually when entering port the ship is under quite limited boiler power, and the boilers that are in use are incapable of supplying the steam without the assistance of the blowers. The use of the blowers is quite apt to be prohibited, owing to the increased supply of cinders which they help spread over the ship's upper deck. The natural result of such conditions is a weak response to backing signals, which it is not fair to blame the turbines for. With sufficient steam supply there should not be a marked difference between the backing qualities of the two types of vessels, though, of course, the small propellers and the high initial tip speed developed with the turbine installation must necessarily be some disadvantage. Again, the location of the two backing turbines on inboard shafts is bad for good results.

OPERATION WHEN FAIRLY UNDERWAY.

Reference is again invited to Figure 1 in connection with a brief description of the manner in which the turbines are used for economical performance at different speeds.

First, for low speeds—up to about eighteen knots—the steam passes through all six ahead turbines, both the high-pressure cruising and the intermediate-pressure cruising being connected up with the four main turbines. Steam admitted to the high-pressure cruising exhausts into the intermediate-pressure cruising, and from the latter it exhausts through separate exhaust pipes to each of the main high-pressure turbines. From the latter it exhausts into the low-pressure turbines, thence into the main condensers.

Second, for moderate speeds—up to about twenty-three

knots—the steam passes through five ahead turbines; being admitted to the intermediate-pressure cruising turbine it exhausts, as before, into the main high-pressure turbines, thence into the low-pressures and into the condensers. The high-pressure cruising turbine revolves idly in a vacuum, its drains being open to the condenser.

Third, for highest speeds, only the four main turbines are used, steam being admitted to each main high-pressure turbine independently, and exhausting in each case through the connected low-pressure turbine and into the condenser. Both cruising turbines revolve idly in a vacuum, their drains being open to the condenser.

Reduction of power in each of the arrangements is obtained by throttling. Increased power is obtained by raising the pressure in the steam belt of the turbine which is being used as the initial stage. In the first arrangement additional power may be secured through the use of a by-pass valve from the first to the second expansion, and also by admitting live steam direct to the intermediate-pressure cruising or to the main high pressures. Similar increase in power may be obtained in the other arrangements. Ordinarily these alternatives are not used, though they are apt to be of benefit at any time.

An expansion coupling is fitted between the cruising turbines and the low-pressure turbine on the middle shafts. The forward end of the low-pressure shafts are built with twelve teeth which engage with a slotted collar bolted to the flange coupling on the after end of the cruising-turbine shafts. This permits of expansion at these points when the cruising turbines are connected, and permits of disconnecting the cruising turbines entirely. The couplings have always worked satisfactorily, but must be lubricated once a week. As but slightly increased efficiency can be expected from the main turbines with the cruising turbines disconnected, and as the joint is not easily broken, the coupling is always kept intact, and the cruising turbines when not in use are run idle in vacuo with drains open to the condenser.

The turbines should run without noise and without vibra-

tion. Such noises as have been mentioned above, if heard while the ship is underway, would indicate unusual conditions which should be investigated immediately. As long, heavy turbine may whip slightly in a sea-way due to the rolling of the ship or the racing of the screws. This might cause the blades to rub now and then and the turbine to groan or vibrate slightly. In very bad weather it has happened to the main high-pressure turbines of the *Chester,* but not sufficiently to cause alarm, being barely noticeable. If the clearances of the dummies were very scant the dummy rings might run a slight risk of grinding for similar reasons, but the likelihood of such an occurrence is very remote. Any grinding at this point would indicate too scant a clearance, and would be very serious, necessitating readjustment at first possible opportunity. To relieve such a situation as the latter the speed should be changed so as to permit of running under the pressure which insures the greatest clearance in this turbine. This should be known from records kept, as will be explained later. On the occasion of a trial trip one of the *Chester's* main high-pressures came into zero clearance and the dummy rings ground on the dummy slightly. At the time, this turbine was under careful surveillance so the situation was handled without difficulty. Clearances should not be carried so small, however, as to allow this to happen. Vibration may always be detected in connection with any such noises, but it is hardly perceptible unless the difficulty is very serious. Slight tremors may be felt when the astern turbines are operated, but they are not noticeable unless looked for. The whistling of wire-drawn steam through throttle valves may at first be mistaken for irregularities in the turbine, but a little experience soon makes it easy to distinguish.

It would appear that greater readiness for service should be expected of the turbine than of the reciprocating engine as overhaul is so seldom necessary and usually of a mild nature even then. Hardly any attention need be paid the turbine proper once it is underway, and no injury to attendants need ever be expected. The advantage resulting from the purity of the steam and its freedom from oil extends to the boilers, con-

densers and feed-water heaters. Barely any cylinder oil is used on the auxiliaries in the engine room of the *Chester,* a mixture of graphite and kerosene proving satisfactory for these engines.

In smooth weather a constant initial pressure, with a steady vacuum, corresponds to a constant speed, but varying conditions of wind and sea, or great variations in boiler pressure have a detrimental effect in this respect. So long as the boiler steam is dry no variation in initial pressure for a constant speed is necessary, but when, with a drop in pressure, the steam becomes wet the effect is felt at once. For this reason the fireroom force must be trained especially to preserve fairly constant limits of pressure. The effect of wind and sea is really marked, and higher pressures become necessary for the same speed, with consequent loss in economy. This is against the turbine, but in spite of it the turbine ship is admirably fitted for heavy-weather work. The turbines do not labor or require throttling, but run with ease and adapt themselves freely to the changes. It may express their action best to say that they appear elastic under such conditions. The beneficial effect from having the wind astern is quite marked. The lower position of the center of gravity due to turbine installations likewise is effective in securing increased stability.

With a sudden change in speed it is found that the turbine does not firmly establish itself to the new conditions for some considerable time. The proper pressure to carry for a specified number of revolutions per minute cannot be exactly determined for nearly an hour, though of course one suitable for the approximate speed can be found in a very few minutes, that is to say, within a quarter of a knot and less. Slight alterations in the pressure carried are apt to become necessary for several hours. More pressure is required before the turbine settles down than after it has become settled. A pressure-revolution table or pressure curve can only be used as a general guide, for such reasons as the above.

Running on a standard number of revolutions per minute is attended with the difficulty of ascertaining from time to time

how many revolutions are being made. With four shafts, all revolving at a high rate, and two of the counters in one engine room and two in another, mistakes are sure to be made. Besides, several minutes are required for the operation. A device connected with all of the shafts that would indicate at the working platform the general average at all times would be a most valuable aid to the throttling. Once the speed is established, however, it is maintained constant with comparative ease, though the man at the throttle must ever be at his station with his eye on the pressure gauge. It then serves to take counter readings about every twenty minutes. The *Chester* proved her efficiency as a guide ship in squadron on a recent run from Hampton Roads, Va., to Bradford, R. I. On this occasion a column formation was maintained, the *Salem* and the *Birmingham* steaming in their respective positions astern with an 800-yard interval. In spite of the marked difference in the types of machinery of the three vessels, perfect distance was preserved from beginning to the end of the run. The officers of the following ships were loud in their praise of the standard speed as preserved by the Parsons turbine. At the beginning of the run they noticed some unsteadiness in it, but when settled down none whatever was noticed.

The *Chester* picks up headway with lightning rapidity. While this to a large extent is due to the fineness of her lines, it is also due to the turbine installation. Maneuvering from rest should be harder with a ship having small propellers, but the turbines may be given steam so quickly and they reach their speed so quickly that I believe for quick ahead action they are, on the whole, superior. I would not like to say the same for astern motion, however.

The two most essential points in connection with the economical operation of the turbine are undoubtedly dry steam and a high vacuum. The *Chester's* boilers furnish a high quality of dry steam, and no ill effects from this source are experienced by me, as a rule. It has already been mentioned, however, that, with a drop in the boiler steam pressure, the quality is affected, and a difference in speed is noticed as a result.

The effect of the wet steam is to cause increased blade friction. Strainers are installed above the throttle valves, but their function is principally to prevent foreign matter, such as might injure the blades, from entering the turbines.

As regards a high vacuum, the reason for its importance lies in the fact that the steam undergoes a greater range of expansion in the turbines than in the reciprocating engine. The theoretical loss due to a drop in the vacuum is usually expressed in terms of percentage of increase in the steam consumption. Such figures perhaps express the importance of a high vacuum most tritely, but it may be expressed also in terms of decrease in speed for the same steam-belt pressure. If running under a constant steam-belt pressure, all other conditions, such as wind and sea, being constant, as well as the vacuum, the speed will be constant. If, however, the vacuum drops, a perceptible drop in the speed will follow. I might say, roughly, that for one inch drop of vacuum on the *Chester* her speed will drop off half a knot. Vacuum being such an important matter, it is well to have an accurate gauge on it. The regular standard type of vacuum gauge is supplied the *Chester,* and also mercury columns. Perfect reliance cannot be placed in them, however, and it is thought that the use of a thermometer at the exhaust end of the low-pressure turbine would be a valuable accessory. Several degrees change in temperature would represent about one-quarter inch of mercury, so that coarse and fine readings could be obtained at this point, which is really where the high vacuum is desired.

The provisions made for the utilization of auxiliary exhaust steam in the turbines has already been referred to above. There are many different conditions under which the auxiliary exhaust steam might be used, sometimes in one place and sometimes in another, depending upon the relative pressure conditions. The advantage to be derived should, however, be determined before it is used. Under some circumstances, as will be shown later, the auxiliary exhaust is drawn off to feed the gland system. Then again it may be used in the feed heaters. If it is used for these purposes there are not many

occasions where it will be found sufficiently plentiful for additional use in any of the turbines. Therein lies a question as to whether greater benefit is derived from its use in the feed heater or in the turbine. I am hardly prepared to speak authoritatively in reply thereto. Benefit is derived in each case. Conditions have been noticed on the *Chester* where its application to the turbines resulted in a half knot increase in speed; whereas, on the other hand, its use in the feed heaters would have provided feed water of a temperature of 230 degrees Fahrenheit or 240 degrees Fahrenheit. Occasionally a surplus, when using it in the feed heaters, is drawn off in the turbines. Special tests along these lines would be of great interest, but I am inclined to the belief that slightly more advantage would be found in the use of the steam in the turbines. On some recent runs the auxiliary exhaust steam was used in the feed heaters only to the extent of keeping the feed water at a temperature of 180 degrees Fahrenheit, and the surplus was used in the low-pressure turbines. There is no advantage claimed for this division in its use. The fire-rooms had been used to having its full benefit in the feed water on most all previous occasions, and on these runs it was thought best to let them down easy merely to avoid misunderstandings in that part of the department. Management of the situation thus proved very satisfactory. When running it into the turbines the dynamo engines may with economy be run open to the back-pressure line, but as a rule a separate condenser is used for that plant.

The gland system on the turbines is one which requires more or less constant attention. As installed on the *Chester* it consists of a main pipe, which passes the entire length of the two engine rooms, forward and after. Branch pipes connect it with each gland of all the turbines, twelve in all. The only valves in the system are on the main pipe. There are two cut-out valves, one to isolate the portions of the main pipe which lie in the respective engine rooms, to permit of independent management, and one to isolate the extreme end of the main pipe which lies abreast the cruising turbines. Neither valves

are ever closed, as the gland system is worked as one unit and independent management in the two engine rooms not attempted; the one for isolating the cruising-turbine gland system would only be used in the event of those turbines being disconnected from the main shafts. There is, therefore, free communication in the system between all glands. The only other valves are one in each engine room for the admission of auxiliary exhaust steam to the main pipe, and a valve in a branch pipe to the condenser with which to relieve any excessive pressure on the system. In order to thoroughly understand the management of the system one must first have a clear understanding of the functions of the glands, especially as these functions are dependent upon existing conditions. The steam gland is, of course, the counterpart of the stuffing box on the reciprocating engine, and is intended to prevent leaks. Where a turbine is under a steam pressure above that of the atmosphere the function of the gland is to prevent the leakage of the steam into the atmosphere, most naturally. On the other hand, part of the turbines are always running under pressure below that of the atmosphere. The initial-stage turbine must always come under the first class, whereas, as the steam takes its course through the successive turbines, some of the latter come under the second class. How many there are of the one and how many of the other depends upon conditions, but the fact remains that, while some of the glands tend to blow steam, others tend to suck air. The amount of steam leakage from glands under internal pressure depends upon the efficiency of the same and cannot be entirely avoided. The effect of the leakage of air through the others into the turbine will be noticed by a drop in the vacuum. As was stated above, the glands are all in free internal communication through the gland-system piping, so the leak-off steam from glands under internal pressure finds its way to the other glands and has the effect of sealing them against air leakage. Some of the steam leakage enters the atmosphere, but that cannot be avoided with the type of gland fitted. The amount of leak-off steam which enters the system is not always sufficient to seal the other

glands, and in such cases auxiliary exhaust steam must be used in addition. On the other hand, the leak-off steam is under some conditions excessive, and it is then that the gland relief valve is opened to draw off the surplus to the condenser. About one pound steam pressure per gauge is ordinarily used on the gland system with good results.

In view of the high speed at which the shafts revolve, a constant and vigilant watch must at all times be kept on the bearings and on the oil system. Once a bearing becomes warm as a result of abnormal conditions it expands, becomes hot and burns almost instantaneously. Experience has taught the necessity for the quickest possible action in such cases by promptly slowing down or stopping, increasing the oil supply and pressure and the water supply to the oil-cooling surface. Care of the bearings and of the oil service equals in importance the skillful warming up of the turbines for service. Several hot thrust bearings have been experienced on the *Chester,* and in all cases they have been due to faulty lubrication in one form or another. In two recent cases they were the result of too close adjustment of float, which, of course, left too limited an oil clearance. In one of these cases it had not been expected, and, indeed, was only discovered upon the occasion of an overhauling shortly afterwards. Then the scorched appearance of the bearing gave testimony. This was an extremely mild case, however, or its occurrence could not possibly have been overlooked. In the other case I detected the bearing myself, first smelling burning oil. I was standing within two feet of the thrust bearing and reached out with my hand to open a small flap door in its casing. Before my hand had touched it the smoke poured out in a cloud. The turbine was slowed down and a temporary adjustment of float effected, as insufficient float was at once known to be the cause of the accident in this particular case. In other cases it was found to be due to rust and corrosion in the thrust, this in turn being a result of water in the oil. At the same time considerable dirt was found in the oil system, and the oil had become in a condition of questionable efficiency. The main bearing jour-

nals are so constructed that, in the event of the babbit melting, certain raised portions of the brass will take the weight of the shaft during the time necessary to slow down and stop. This is in order to save the stripping of the blades, which otherwise would be a natural consequence. The use of the hose on the bearing casing when a hot bearing develops is a useless alternative, though after the turbine is stopped it can do no harm to reduce the temperature. Sight glasses are fitted in all of the branch discharge pipes from bearings, and a glance at these shows whether or not the flow of oil is normal. Thermometers are also fitted at these points and the temperature of the oil discharged from each bearing is readily observed. Care should be taken to see that the stems of all thermometers extend to a point where the oil washes over them so their readings will really represent the temperature of the oil proper. The oilers in making their rounds should not be guided entirely by these devices, but should feel each bearing with the hand. In the tropics the oil gets thin and all bearing temperatures rise. They have ranged between 110 degrees Fahrenheit and 115 degrees Fahrenheit, whereas under ordinary conditions they run from 100 degrees Fahrenheit to 105 degrees Fahrenheit. The oil first used on the *Chester* was of the brand used by the builders of the ship, but shortly afterwards the Government made an annual contract for turbine oil of a different brand, and since that time the latter brand has been in use. Oil of the first brand was used for nearly five months, and during that time considerable difficulty was experienced. While it was not all attributed to the grade of oil, still the brand now used is considered on the whole more satisfactory. No calculations have been made on the amount of oil required for operation, as sufficient time has not lapsed since the remedying of certain difficulties at first experienced, but the tremendous oil saving with the use of turbines is most apparent. On one occasion, early in commission, oil of different grade, intended for use on auxiliaries, was accidentally placed in the system and ruined the oil then in it. This necessitated a cleaning out of the system and the replenishing of the supply. Later, water

appeared in the system in a greater quantity than could be accounted for, but this finally ceased, after more frequent attention to gravity-return oil tanks. Then, again, much oil was lost from the after spring bearings on both inboard shafts, particularly in the tropics, where the oil was thin, and also at times when the ship was much down by the stern. The latter condition affected the gravity return of the oil to the tanks. Independent return pipes are now installed from these bearings and but little loss has taken place to date. The first oil seemed to change color after a short time in use and had to be renewed at frequent intervals. It finally became soapy and white, and the whole system was boiled out with steam and water before the new brand of oil was tried. A precaution that should be observed is the daily inspection of the gravity-return oil tanks when in port for the presence of grit, dirt or an excessive amount of water. The water can be drawn off, but if it is excessive steps should at once be taken to ascertain where it comes from. It should not come from the coolers, on account of the oil pressure being greater than the water pressure, but this is one place that should at least be inspected. Another place is in the water jackets on the spring bearings. The water should, of course, be tasted first to determine whether salt or fresh. It is surprising how much water may be expected from sweating. Reference is invited to Figs. 7 and 8.

The measure of horsepower is determined by the use of a torsion meter, one of the Denny & Johnson type having been used on the *Chester*. There is little need for such an instrument in service, and the one now installed is only for use during the special trials being conducted for information as to the relative merits of the types of machinery on the three scout cruisers. The torsion of the shaft over a certain length is shown by this instrument, and, the shaft having been calibrated previous to installation, the brake horsepower is determined by a formula covering the principle involved.

The marked effects of cavitation supposed to exist when high power is reached exist more in fancy than in fact. The second standardization trial of the *Chester* conclusively proved that she

had made all speeds that had ever been claimed for her. The efficiency of the propellers falls off at the higher speeds, but not to an alarming extent, and no evidence of their breaking down or of erratic behavior has ever been detected. New propellers of even greater disc area are to be fitted later and slightly greater speed is expected.

My remarks on operation must be brought to a close after mention of the following points to be observed when securing the turbines after coming to anchor. Steam should be tightly shut off the glands and off the vacuum augmenters. Special precautions should be taken to see that water service is kept on the vacuum-augmenter condensers, however, and the main air and circulating pumps should be run for about three hours after steam is shut off the turbines. The latter is necessary, as hot vapor remains in the turbines and develops for a considerable time after the steam and water has been drained out, and the condensers might be damaged if secured too early, even after securing condensation continues for a considerable length of time, for the turbines remain more or less warm from twelve to twenty-four hours, depending on the surrounding temperature.

THE ADJUSTMENT OF DUMMY CLEARANCES.

The clearance between the dummy piston and the dummy rings is a direct gauge on the leakage of steam from the steam belt. Fig. 4 roughly illustrates how the dummy rings are fitted to the dummy casing and how the serrated faces on the dummy piston revolve in close proximity to the sharp edges of these rings. The importance of preserving a fine adjustment of this clearance as regards the prevention of leakage is apparent. Likewise, the adjustment must not be too fine or the dummy rings would be stripped and the turbine put out of commission. Further reference is invited to Fig. 5, which shows the relative location of these parts to the other parts of the turbine. The adjustment of these clearances, when necessary, is accomplished through the adjustment of the lower

and upper halves of the thrust blocks, primarily of the former. Fig. 4 illustrates this to some extent, while Fig. 6 shows a top-view plan of the lower half of a thrust block. The position of the lower half of the thrust block is fixed by the brass half rings, which are fitted around it in recesses. These rings are called keep rings, and the forward one of the two is the one of vital importance, as the after ring is merely put in to make up for the slack and need not be a fit closer than to a few thousandths of an inch. The thickness of the forward ring marks the limit of the forward movement of the lower half of the thrust block, which, in turn, limits the forward move-

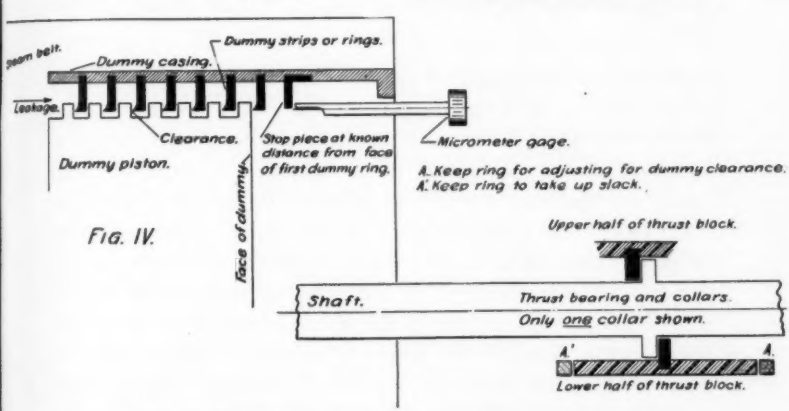
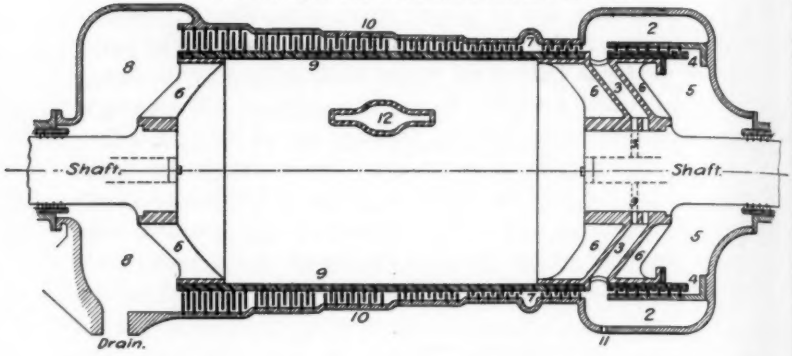


FIG. IV.

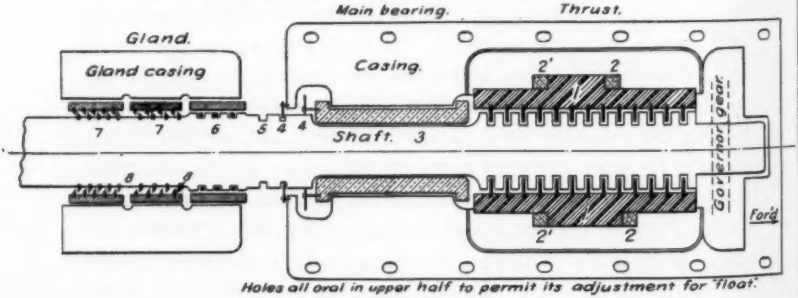
ment of the shaft itself, and in consequence of the latter the limit is established of minimum clearance between dummy and dummy rings. The upper half of the thrust block is contained in a casing which is bolted to the casing in which the lower half is contained. The bolt holes are oval in shape to permit of fore-and-aft adjustment of this upper casing before firmly bolting the two together. The adjustment of the upper thrust block is for the purpose of allowing for float. By this is meant the amount of clearance in the thrust bearing for lubrication. In the Parsons turbine the lower half of the thrust block takes only the propeller thrust. The upper half is intended to take the steam thrust only. The turbines are designed to be steam

FIG. V. MAIN H.P SPINDLE, ROTOR AND CASING.



balanced, the end thrust on the rotor and the unbalanced thrust on the blades, both resulting from the steam pressure, which acts in the opposite direction to the propeller thrust, being so calculated for in designing as to balance the latter at practically all speeds. Perfect equilibrium is not possible, however, and under some pressure conditions the steam pressure preponderates, while under others the propeller thrust preponderates. When the latter is the case the shaft comes all the way in and the lower half of the thrust block takes the strain. On the other hand, if the steam pressure is greatest the tendency of the shaft is to run out and the steam thrust is taken up on the upper half of the thrust block. The amount of fore-

FIG. VI. LOWER CASING. MAIN H.P. TURBINE. TOP VIEW.



and-aft play in the bearing to accommodate these conditions and likewise to permit of oil clearance is the float. It must be at least .002 inch, as that is the thickness of a film of oil, and it must not be too great or it will permit of too large a dummy clearance; whereas the keep-ring adjustment of the lower thrust block limits the least clearance, the position in which the upper half of the thrust block is bolted limits the greatest clearance. It may be said for the turbines of the *Chester* that a float of about .010 inch should be allowed. The figure .002 inch, supposed to represent the thickness of a film of oil, is known by experience to be entirely too fine a figure for practical consideration. It was never used in service, but while making an adjustment on one occasion only .002 inch float resulted, causing the heating of a bearing. As regards the primary adjustment, that of the lower half of the thrust block for "least clearance," it must not be made to approach too nearly zero, as wear in the lower thrust bearing to a slight extent must be expected and would reduce the clearance to a dangerous figure. The wear should really be inappreciable, as the balance feature of the thrust minimizes the strain on the thrust bearings. The faces of thrust collars on the *Chester* were at one time affected by corrosion, and a few thousandths of an inch reduction in clearance resulted from cleaning and stowing them. Twenty-five thousand miles of steaming has not affected them except to a few thousandths of an inch.

The dummy clearance is determined by micrometer gauges fitted to the casing of each turbine. The device consists of a spindle stem, which passes through a stuffing box in the casing and into the turbine. (See Fig. 4.) The end of the stem is recessed on one side to permit of its passing clear of a stop piece. The position of the stem in the figure is with the end of the stem against the stop piece. A reading of the gauge is taken and the stem then turned half around to clear this stop piece. The end is next placed against the face of the dummy piston and another reading of the gauge taken. This is not considered the proper sequence in which to take the readings, however. I personally believe that the rule should be followed

of taking the first reading on the dummy-piston face, so that, at the conclusion of the second reading, the end of the micrometer stem will be in its "secure" position. When the reverse order is followed the one who took the readings might neglect to pull the micrometer back into its "secure" position and its spindle end would grind on the dummy face and burr, perhaps get hot also and bend. Besides, it might cause alarm by making a noise which could not immediately be accounted for. The difference between the two readings is the distance between the face of the dummy and the face of the stop piece. A known constant, representing the distance between the face of the stop piece and the edge of the first dummy ring, is subtracted from the difference between the two readings, and the result is the clearance between edge of first ring and face of dummy piston. This represents as well the clearances of all the dummy rings, as they are all spaced perfectly and at equal intervals. The two cruising turbines are on No. 2 and No. 3 shafts, respectively, their part of these shafts having an expansion-coupling connection with the remaining part. Owing to the nature of this coupling no propeller thrust is experienced in the cruising-turbine thrust bearings and a very slight clearance is necessary. The same type of bearing is fitted, however, and adjustments made in the same manner. An important point is the examination of the ends of micrometer spindles from time to time. Burrs may develop and cause inaccurate readings. Inaccurate readings are also possible if the face of the dummy pistons rust and blister. While this is not likely to happen, it might, after a long stay in port with the turbines idle. Rust on the internal parts of the turbines is insignificant in extent as a rule, even after comparatively long rests, and should cause no anxiety.

Different clearances in the same turbine are found for the different conditions that exist. As previously explained, the float is one reason, accounting, as it does, for a greatest and least clearance. The clearances also vary with the temperature. It would not be easy to secure greatest and least clearances when the turbines are cold, but if it were it would be

found that they would not agree with those obtained when the turbines were warmed for getting underway. Neither would it be found that these limits of clearance, could they be obtained under the latter conditions, would quite agree with those obtained with the turbines thoroughly warmed as when underway. The differences between greatest and least in each case would possibly be alike, but the greatest clearances would differ slightly from one another as would the least clearances. In the construction of the turbine provision is made to minimize any such differences, though it is an open question whether the means adopted are beneficial. The arms of the wheel to which the rotor is secured at its forward end are cast hollow and open into a recess in the center of the shaft, this to permit these spaces as well as the hollow shaft to be always filled with steam and automatically regulate the conditions of expansion, so that uniform dummy clearances will exist for varying conditions of temperature. Finger pieces are fitted with ends running in a recess in the shaft, as shown in Fig. 6. These are such crude affairs that their use for very fine adjustments would be impossible. They are merely alternatives to be used when conditions demand. Considerable practice is necessary with the micrometer gauge before becoming proficient. The reading depends on the touch, and even a difference in reading of .001 inch by two different persons must be expected. In taking readings underway for certain conditions of pressure and speed one should wait until such conditions have become settled. It may take several hours before the turbines find their true position, though such a long delay in securing readings is only necessary for accurate records and knowledge. Adjustment for clearances is exceedingly delicate work, and none but the most careful men must be allowed any part in it. It should only be undertaken when necessary, and should not be necessary except at long intervals. It should also be avoided until a thorough confidence is had in one's knowledge of conditions. A careful record should be kept of the sizes of keep rings installed and in what position in each bearing block. They should have their thicknesses stamped on their peripheries.

Guide stems with lock nuts are fitted to the casings which contain upper-thrust blocks for the purpose of gauging the change in position of such casings when regulating the float. The nuts on these stems must be handled judiciously or they will cause much mischief. Once adjusted, they must be let alone. A historical record of changes made in keep rings and of alterations in the float should be kept. The best method of adjusting the float is to pull the spindle in until top and bottom bearing surfaces in the bearing are in firm contact, thus leaving no float. The guide stems above referred to should then be adjusted so that their ends are open by the amount desired for float, the adjusting nut being properly set to correspond. Then, by a stroke of a sledge hammer, the casing containing the upper-thrust block can be knocked into position and all holding-down nuts set up on and guide-stem locking nuts secured.

A complete record of micrometer readings should be kept, for otherwise a true knowledge of the turbine clearances cannot be had. The record, to be of real value, should show the pressure conditions under which the readings were taken. It is well to take an occasional set of readings when the turbines are cold, and a set should always be taken when the turbines are warm, just before they are tried. They should always be in sets, including the clearances in all of the turbines. When underway they should be taken daily, and with each change of speed, if the new speed is to be maintained for sufficient time to warrant it. A note book is recommended for keeping these records, with pages arranged in table form. The following suggestion is offered:

Date.	Approx. speed.	.....	H. P. C. *lbs.*	I. P. C. *lbs.*	S. H. P. *lbs.*	S. L. P. *ins. vac.*	P. H. P. *lbs.*	P. L. P. *ins. vac.*
May 1, 1909	12 knots.	Gauge pressure.	85	22	10	23.5	7	22
		Clearance.....	*in.* .009	*in.* .015	*in.* .014	*in.* .021	*in.* .018	*in.* .028

While it has nothing to do with dummy clearances and their tabulation, it might also be suggested that in the same note

book there be kept a record of bridge-gauge measurements on journal bearings in the following form:

	April 1, '08.	Oct. 1, '08.	April 1, '09.
H.P.C. forward bearing.....	.018	....	....
after bearing.....	.027	....	....
I.P.C. forward bearing.....	.032	....	....
after bearing.....	.012	....	....
S.H.P. forward bearing.....	.038	....	....
after bearing.....	.010	....	....
S.L.P. forward bearing.....	.022	....	....
after bearing.....	.021	....	....
P.H.P. forward bearing.....	.023	....	....
after bearing.....	.008	....	....
P.L.P. forward bearing.....	.019	....	....
after bearing.....	.002	....	....

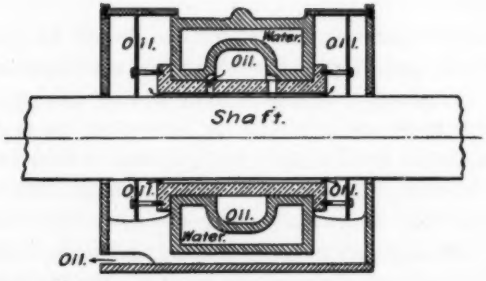
UPKEEP.

Successful operation of the turbine should be possible for an indefinite period and necessitate but the slightest amount of work of upkeep. In one year of service, during which the turbines have driven the ship 25,000 miles, no repairs have been effected on the *Chester's* turbines that required more than one day's work, and even these repairs have been very few. The large jobs which might become necessary, such as re-blading, refitting dummy rings and realignment of shafts, need seldom be expected if the operation of the turbine is conducted with care. The realignment of a short length of shafting on the *Chester* is soon to be undertaken, as this particular length, in finding its true alignment, wore down its bearings about .005 inch, and this had a detrimental effect on the gland-packing strips, causing undue leakage. With a new installation some such incident as this must be expected, and it is safe to say that when this repair is effected it will last for an almost indefinite period. The examination of the turbine internally should not be necessary except at very long intervals. It is understood that the British requirements on merchant marine

installations call for the opening of one pair of the *Mauretania's* turbines annually. I had the pleasure of attending the acceptance trials of the turbine steamer *Camden,* built by the Bath Iron Works, Bath, Maine, for the Eastern Steamship Company, and became familiar with her turbines in that way. Her trials were held in May, 1907, and she was placed in service a few days after the trials and remained on her route through the summer and fall. She was laid up for the winter at the Bath Iron Works, and in the spring her turbine casings were lifted. There was a small amount of core sand and light dust found, but it had done no harm and might almost as well have been left undisturbed. The blading was intact and the rust appearance was too slight to be worthy of mention. The writer can hardly agree with a statement read by him in a text-

FIG. VII.

LINE SHAFT BEARING.



book which, in barely touching upon turbine matters, gave the impression that it was necessary to lift the top casings once in three months in order to clear the blades of red lead, etc., despite the steam strainers. The steam strainers of the main turbines of the *Chester* were examined before her recent twenty-four-hour full-power endurance trial and were in perfect condition. Not having been examined before during her one year in commission, an especially careful examination was made. No doubt the top casings should be lifted after the turbines have been first tried, and this is usually done in our

Navy on the occasion of the post-trial examination by the Board of Inspection. Owing to the liberal amount of head room usually found in turbine-engine rooms, the facilities for lifting these top casings makes it no very difficult operation. Indeed, the breaking and remaking of joints and tearing away and replacing of lagging is the greater part of the work. Turbine builders, while engaged at installing, with their facilities at hand and their men in training, think nothing of lifting and replacing a top casing on the same day. The large surface joints between the two casings of the *Chester's* turbines are all made up with a preparation called manganesite. It comes in the form of bricks, and is broken up and mixed with raw oil. It then resembles graphite in a sticky form. It proves very efficient for joints of this nature. Only in one small place has it blown out, and, while this will eventually necessitate the remaking of the joint, the leak has been stopped thus far by the application of rust cement. The leak referred to is in a very awkward place, near a gland-casing joint. The result is that the gland-casing joint has been affected and it has had to be remade on several occasions. After remaking this gland joint the turbine was put under heavy pressure, its exhaust valve being securely closed. It can thus be seen that a perfect test was practicable without the turbine turning over to the slightest degree.

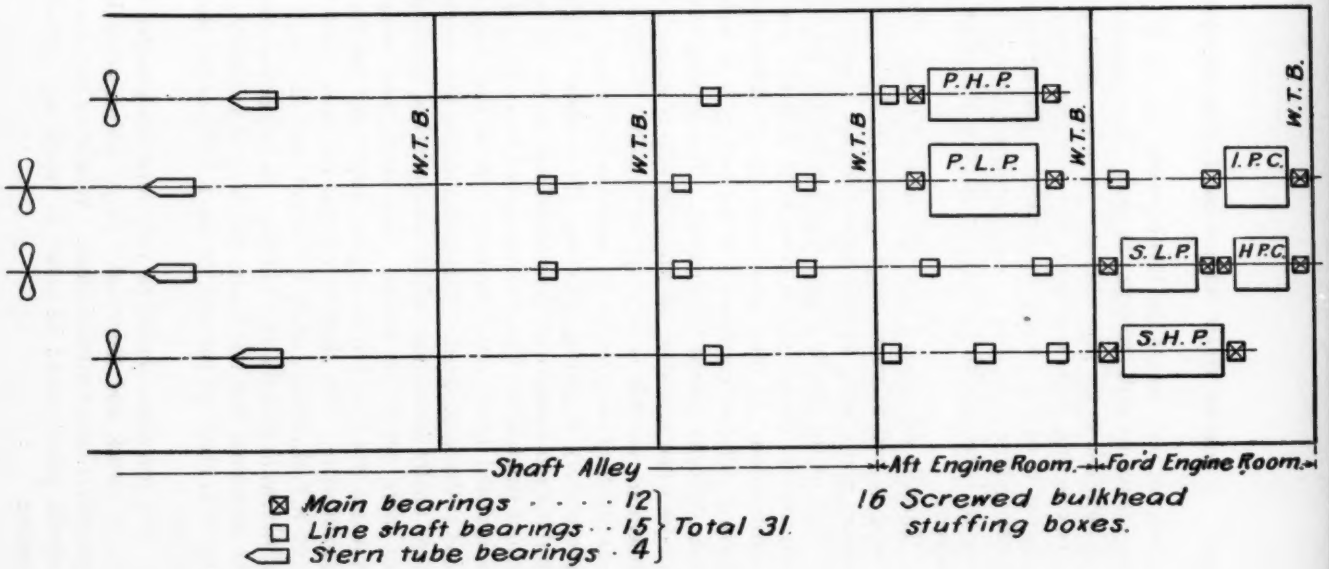
It is perhaps wise to examine the main bearing journals about every six months after commissioning and check them up with their original positions. For this purpose bridge gauges are supplied. They are spans which are bolted firmly to the bearing casing and have a center point. Between this center point and the journal the height is measured. Records of these should be kept whenever such examinations are made. The first examination may be expected to show the bearing to be down not more than one or two thousandths of an inch below original heights. The next examination should really not be necessary sooner than a year. With one or two exceptions, the bearings of the *Chester* are in almost their original positions.

For some unknown reason I conceived a notion before beginning active operations with the turbine that my troubles would be mostly with the glands. Such, however, has not been the case. Still these devices must meet with their share of criticism. They are no doubt the only practical solution to the problem involved, on account of the high surface speed at which the shafts revolve, but they do leak an abnormal amount of steam, and improvement in them must be looked for. They are packed by strips bedded on the one side into the shaft and on the opposite side into the gland sleeves. The thin edges of these strips just clear the opposite member. Snap rings are fitted at the outer end of each gland box, in addition, to prevent the leakage into the atmosphere of such steam as may wiredraw past the packing strips. My notion was that these snap rings would break and need frequent renewal, but no such need has ever developed and is no longer expected. On rare occasions a click, click, click, has been heard in the gland box, caused by these snap rings not having found their running position promptly, but it would die away in a couple minutes and never recur. These rings run loose in slots, tightly fitting, and are so cut that they can be spread and passed over the thrust and gland collars to be put in place. In connection with the realignment of the short length of shaft previously referred to, the fitting of new packing strips in the glands will be necessary. The effect of wear-down of the bearings in question was to cause the gland-packing strips in the glands to wear down their edges. This naturally reduces the efficiency of the gland and causes undue leakage through the same. The repacking of this gland will be a very neat job, as a wearing fit must be made. On the Curtis turbine these glands are made tight by rings of carbon, the rings being made up of several sectors, each of the sectors being held fairly tight against the shaft by flat springs. Between the successive rings fitted a steam seal is applied. This type of gland is quite successful, but is not considered suited to use with Parsons turbines on account of the friction due to high surface speeds.

The leakage of steam through the glands and into the engine

FIG. VIII.

ARRANGEMENT OF SHAFTING AND BEARINGS.



room not only means the loss of steam but the filling of the engine rooms with dampness as well. This dampness is most disagreeable to the personnel and has a bad effect on lagging, pipe covering, decks overhead, etc. For this reason good ventilation is of the utmost importance. The turbines make a hotter engine room than a reciprocating-engine room, but when the air is laden with moisture in addition the effect is doubly severe.

Throttle valves must be a tight fit at all times. The turbine being so well balanced, turns its shaft on the slightest provocation, and a leaky throttle valve becomes a serious nuisance. Valves of the double-poppet type are hard to keep in perfect adjustment, though this is considered as partly due to faulty construction. If they were made up of different materials, having different coefficients of expansion, it is believed that this difficulty would be obviated. The turning over of the shafts when at anchor, or when the ship is stopped, cannot be tolerated, yet this is very apt to happen. To illustrate how readily they revolve, on an occasion for trying the turbines preparatory to getting underway the starboard high-pressure turbine was turned over slow ahead and the throttle valve then closed hand-tight. The shaft continued to revolve and the valve was closed tightly with a wrench. Still the shaft kept in motion and at the same speed. This continued for five or ten minutes, until finally the vacuum, which was 29 inches, was broken down to more nearly 20 inches. The shaft then stopped. The vacuum was raised to its original height, but the shaft did not again move. The shaft before this had been revolving about 100 R.P.M., which, while it does not represent much power, is sufficient to give the ship motion. In this connection it might be mentioned that idle shafts will drag at a number of R.P.M. equal to about 50 per cent. of the R.P.M. of the shafts under steam.

The propellers should be very carefully guarded so as not to be struck and deformed. Slight deformation in turbine propellers have a marked effect. Whenever they are examined special pains should be taken to repair any defects of this nature.

PERSONNEL.

No good opportunity has been had to make fair comparison of the relative demands of the two types of machinery, turbine and reciprocating, in this respect, but there is believed to be no very great difference. There should be a saving in the number of oilers required at high powers on turbine vessels, but at lower powers the same numbers would serve both types. As regards machinists, there should be more demand for them around reciprocating engines, as more overhauling is undoubtedly necessary. As regards the type of machinists, the most skilled hands should, of course, be selected for service with the turbine, for such work as is necessary is of a delicate nature.

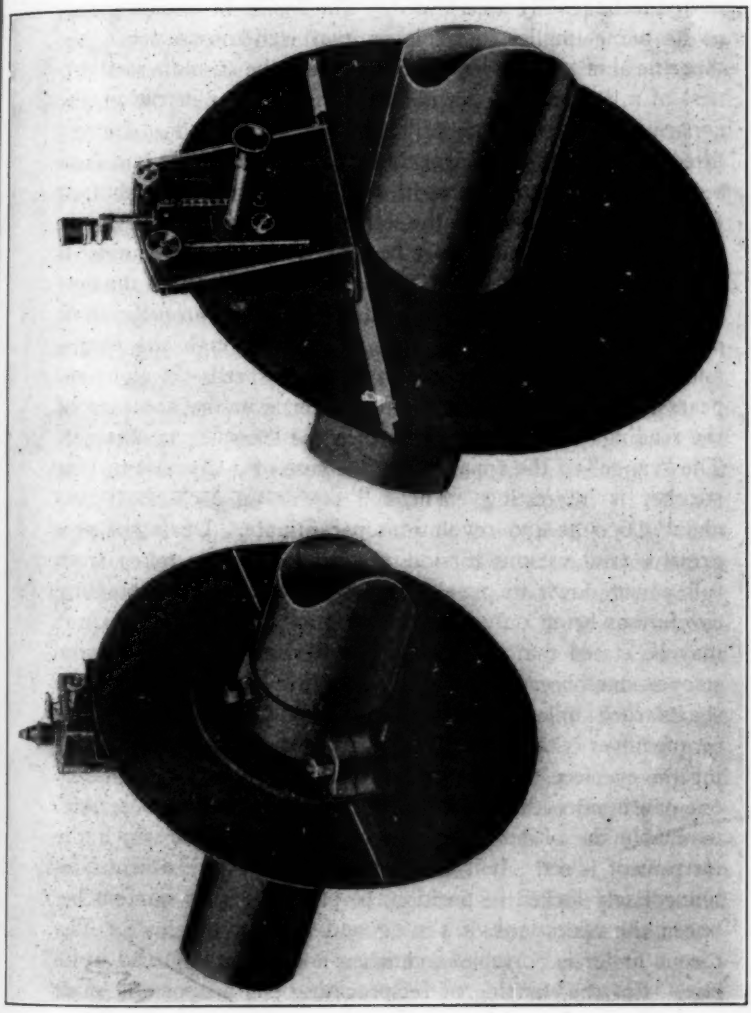
DIGEST OF NOTES ON TORSION METERS.

In the following pages are extracts of recently-published discussions on torsion meters and the general subject of means for measurement of shaft horsepower. Several of the different types described are to be used on the trials of the new turbine vessels for the U. S. Navy. The different kinds will include the Johnson-Denny type, Foettinger. Chadburne Flashlight torsion meter, and also a new Mitten type built by William Cramp and Sons. With the steam turbine the torsion meter takes the place occupied by the engine indicator of the reciprocating engine. For this reason the principles of the construction and the methods of operation of these instruments are of particular interest to naval engineers.

CHADBURN'S FLASHLIGHT TORSION METER—(BEVIS-GIBSON PATENT).

It is over a century ago since James Watt invented the steam-engine indicator, and that instrument, long since brought up to perfection, has up to a few years ago been in universal use. The advent of the steam turbine has caused a change, while the indicator is very suitable for reciprocating engines, it is useless for turbines. An instrument for measuring the horsepower of turbine engines was required, and several have been invented. The most recent is Chadburn's flashlight torsion meter (Bevis-Gibson patent), which is manufactured and supplied by Chadburn's (ship) Telegraph Co., Ltd., Cyprus Road, Bootle, Lancashire.

As will be seen from the accompanying illustration, the instrument is extremely simple and can be operated by any practical engineer, by whom the reading can be taken to the one-four hundredth part of an inch. The instrument is for



CHADBURN'S FLASHLIGHT TORSION METER.—BEVIS-GIBSON PATENT.

measuring by direct observation the exact angle of twist in any revolving shaft, and thus enabling the horsepower transmitted to be readily ascertained. The flashlight torsion meter, as its name implies, depends on two well-known principles, viz: the almost infinite speed of light and the absolute straightness of a light ray. As will be seen from the illustration, the apparatus consists essentially of two instantaneous shutters fitted to the shaft at a reasonable distance apart. At one shutter is a brilliant source of light which flashes along the shaft at each revolution, and at the other shutter is a receiver or "torque finder," which must be moved to the exact angle of twist of the shaft before the flash can be seen through the eyepiece. In a rapidly-revolving shaft, such as the propeller shaft of a turbine steamer, the light as seen through the torque finder is practically continuous; at lower speeds the light appears to flicker, but there is no difference in the accuracy of the readings or the ease with which the "torque" is obtained. The "range" of the apparatus in the case of a Channel turbine steamer is interesting. The full power on each shaft was about 2,600 at 470 revolutions per minute. During a progressive trial various torsion-meter records were taken from full power down to 9.2-shaft horsepower, the corresponding revolutions being only 24.4 per minute. In this connection it may be stated that during the recent trials of a 33-knot destroyer, one observer was able to get the horsepower of three shafts each mile, namely, in less than two minutes. The torque finder is the most delicate part of the apparatus, containing the eyepiece, vernier scale (for reading down to angles of one-one hundredth of a degree), and a magnifying "reader" to enable the observer to see the exact angle at which the instrument is set. It is set by a micrometer adjustment, and immediately locked in position, to prevent any movement between the operations of setting and reading the scale. The torque finder is portable, and when not in use is placed in its box. For the shafting of reciprocating engines, or any shaft exposed to a fluctuating torque, means are provided enabling an observer to take twelve or more readings in one revolution.

When these torque readings are plotted out on a development of the crank circle, as in a twisting-moment diagram, the resultant curve is found to approximate very closely to the diagram built up from the indicator cards of the engine. The difference between the two curves shows, with remarkable accuracy, the power absorbed by engine friction.

The degrees of torque having been read from the torsion meter and the revolutions ascertained, these are referred to the power diagram, and the shaft horsepower is read off at a glance. Each shaft is, of course, calibrated separately. The directions for the operation of calibrating shafting given by Messrs. Chadburn are as follows: 1. Select that portion of shafting (whether one or more lengths) that is to be utilized for torque readings, and fit same securely together with their own coupling bolts. 2. Take a rigid base and head stock, such as a lathe bed or heavy floor plate in the shops. 3. Secure one end of the shaft rigidly to the head stock or angle plate and support the other end in a plummer-block bearing so that it can rotate easily without movement of the axis. 4. To the free end of the shaft secure rigidly two opposite levers to form an exact couple, and to the ends of the levers attach heavy chains and stretching screws with graduated-spring balances; one to pull up, the other to pull down. 5. On an exact-measured length of the shaft (preferably at the points where the discs will be fitted) fit two light pointers, their ends moving over fixed wood battens, to which can be pinned slips of paper to record the movements of the pointers. 6. To add the compression caused by the propeller thrust, fit two long tension bars parallel with the shaft and of such section that the maximum stress shall not exceed 10,000 pounds per square inch. 7. Introduce a hydraulic jack between the bridle joining the ends of the tension stays and the free end of the shaft, a ball race being fitted at the free end of the shaft to eliminate friction. 8. Calculate the maximum twisting force that is likely to be transmitted by the shaft by the formula A and the maximum thrust by the formula B. 9. Having marked the zero at both pointers, proceed to twist and compress the shaft up

to the maximum (and, say, 25 per cent. beyond), advancing by increments of, say, 25 per cent., and mark the positions at both pointers, giving each mark an identifying number. 10. During the time the stresses are being applied tap the shaft constantly with a lead or copper hammer to keep it "alive" or in a state of molecular vibration. 11. The loads should be released in corresponding increments and the positions marked as before. 12. If the shaft is perfectly elastic the pointers will return to zero and the modulus of rigidity can then be calculated by the formula C. 13. It is quite possible that both pointers will not return to zero, which will be because of some slight movement at the fast end of the shaft, due to key or bolts giving slightly, but the differences between the two pointers will give the true torque. 14. Having got the modulus of rigidity for the shaft, the horsepower can then always be calculated by the formula D, or a diagram can be made for each shaft from which the horsepower can be read off more readily. 15. It is always advisable to repeat the calibration experiment to eliminate any slight errors of observation. 16. If it is inconvenient to apply the thrust stress, a sufficiently close approximation is to deduct 3 per cent. from the ascertained modulus of rigidity due to torque alone in the case of hollow shafting where the hole is not more than half the outside diameter. For solid shafting 1 per cent. is sufficient to deduct. 17. Care should be taken in applying the torque to see that *both* graduated-spring balances record the same load before the marks are made.

The torsion meter has already been used on a number of turbine steamers. On the Great Western Railway Co.'s turbine Channel steamer *St. George* the results were found to be extremely accurate, even down to a very low power. Messrs. Vickers, Son & Maxim applied it on board the very fast Isle of Man Steamship Co.'s new turbine steamer *Ben-my-Chree* with satisfactory results. It has been tried in the British Navy on board a battleship of the *Dreadnought* type and on the 33-knot torpedo destroyers, and has been supplied to the French, Italian and American navies.

The following are the formulae for calibration of shafting in the shop:

Formula A. $T = \frac{\text{I.H.P.} \times 59{,}880}{N}$.

Formula B. $P = \frac{\text{I.H.P.} \times 196}{S}$.

Formula C. $M = \frac{T \times L \times 584}{\theta \times D^4}$ (for solid shafting);

or $= \frac{T \times L \times 584}{\theta \times (D^4 - d^4)}$ (for hollow shafting);

Formula D. $H = \frac{\theta \times D^4 \times N}{C \times L}$ (for solid shafting).

or $= \frac{\theta \times (D^4 - d^4) \times N}{C \times L}$ (for hollow shafting);

where $C = \frac{36{,}820{,}000}{M}$.

In the above formulae the symbols represent the following quantities:

T = Twisting moments in inch-pounds.
I.H.P. = Designed indicated horsepower.
P = Maximum thrust in pounds.
S = Designed speed of ship in knots.
M = Modulus of rigidity in pounds.
L = Length of shaft measured in inches.
θ = Angular displacement in degrees.
N = Number of revolutions per minute.
D = External diameter of shaft in inches.
d = Internal diameter of shaft in inches (if hollow).
C = Constant depending on M and determined as shown in formula D.
H = Horsepower transmitted.

The following table shows some very interesting results:

TURBINE STEAMER.

FLASHLIGHT TORSION METER. ACTUAL READING AND CORRESPONDING HORSEPOWERS TAKEN DURING TRIAL TRIPS UNDER VARYING CONDITIONS OF DISPLACEMENT AND PROPELLERS.

Turbine Shaft.	Torque, degrees.	Revolutions per minute.	Shaft horsepower.	Shaft horsepower, total.
Starboard, low pressure	1.43	482.9	2,775	7,975
Center, high pressure	1.69	461.1	2,600	
Port, low pressure	1.37	472.8	2,600	
Starboard, low pressure	1.32	461.2	2,410	6,940
Center, high pressure	1.65	426.8	2,330	
Port, low pressure	1.24	457.3	2,200	
Starboard, low pressure	1.15	426.4	1,970	5,960
Center, high pressure	1.52	417.6	2,080	
Port, low pressure	1.13	418.9	1,910	
Starboard, low pressure	1.05	418.4	1,765	5,555
Center, high pressure	1.52	422.3	2,120	
Port, low pressure	1.02	415.5	1,670	
Starboard, low pressure	0.21	198.6	162	495
Center, high pressure	0.27	206.3	185	
Port, low pressure	0.19	183.5	148	
Starboard, low pressure	0.22	146.7	88	257
Center, high pressure	0.21	171.4	87	
Port, low pressure	0.13	144.8	82	
Starboard, low pressure	0.07	46.3	13	37.2
Center, high pressure	0.05	86.1	15	
Port, low pressure	0.01	24.4	9.2	

The above results show clearly the great range of the apparatus. Some of the low powers recorded are less than half of 1 per cent. of the full power. If indicated horsepowers of such small amount were required to be taken from a piston engine, the indicator spring would have to be changed for a very weak one to get a reasonably accurate card; but no such change is required in the apparatus.—"The Steamship."

THE MECHANICAL EFFICIENCY OF MARINE ENGINES.

The recent paper on "Torsion Meters in Marine Work," read by Mr. J. Hamilton Gibson, of Cammell, Laird & Co., Limited, at the Northeast Coast Institute of Engineers and Shipbuilders, not only embodied some very interesting information on the subject, but stirred up a discussion on the part of actual users and other inventors that added considerably to its value. As with all generous papers on a new subject, many critics asked for further information, while others desired greater assurance of the accuracy attained by these instruments, and for some proof of their having been checked by reliable means.

Although the late Mr. Froude, as long ago as 1877, was fully aware of the importance of determining the brake horsepower as opposed to the indicated power, and even went as far as to suggest, in a paper read before the Institution of Mechanical Engineers in 1877, a method of obtaining this accurately on board ship, little or nothing was done in England before the adoption of the steam turbine rendered such information essential. When any data was desired as to the power absorbed by friction in the main engines, the method invariably adopted was to run the engines with the ship moored and the propeller either removed or the shafting disconnected. The power as ascertained by indicator diagrams at the various revolutions was then calculated, but could be obviously only an approximation to what it was when the engine was working, owing to the fact that the full load on the bearings or thrust block is not exerted under those conditions, and that in the case of disconnected shafting the parts rotated are not the same as when the engine is at work. Under these circumstances the power required to run the engine up to speed has been found to be somewhere between 5 and 10 per cent. of the normal full power, but accurate determination of the indicated horsepower is not easy to arrange owing to the difficulty of keeping the revolutions constant when the engine is running free.

Data from ships at sea running at exceptionally low revolutions are very scarce, and little information is gained in this

way about the mechanical efficiency of marine engines. Cases have been known where large battleships have been tried and the power measured at as low a speed as 3 knots, and destroyers have been run at 2 per cent. of their full power for long trials, but the information gained is not very great. On one occasion H.M.S. *Hyacinth* was found to develop 61.0 indicated horsepower at 15.7 revolutions, which showed that her engine friction could not be excessive, and perhaps the most important series of comparative official trials on the power taken to run the engines light was that carried out by the Boiler Committee on that vessel and the *Minerva* at Devonport in February, 1902. The propellers were removed, and the engines were run over a very wide range of speed; special springs were used in the indicators, and every effort was made to ensure accurate information being obtained. The results shown graphically in Fig. 1 are very similar for the two ships, and prove that the

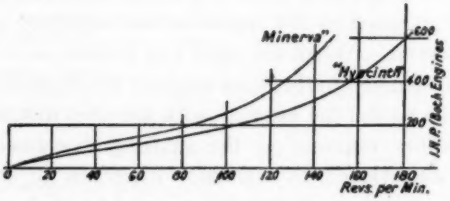


Fig. 1.—I.H.P. ABSORBED BY FRICTION.

engine friction amounted in each case to about 5 per cent. of the power when the engines were run at full power. From these and other similar trials made by private firms, the general deduction had been made that the power delivered to the propellers was within 5 to 15 per cent. of that indicated in the cylinders.

For many years no attempt was made to obtain the brake horsepower, and thus arrive definitely and accurately at the mechanical efficiency, and before discussing the question of mechanical efficiency, and of the relative efficiency of turbines and reciprocating engines, we propose to deal with the methods

of arriving at the brake horsepower while the engines are at work.

Various systems of torsion meters were described by Mr. Gibson in his paper, and to him belongs the credit for publishing, for the first time in this country, a series of curves showing the actual twisting moments as found by the Bevis-Gibson meter when used on a reciprocating engine. To measure the deflection of a shaft revolving under a constant torque is comparatively simple; but the matter is much more complicated when the fluctuating nature of the power applied by the engine causes irregular oscillations in the angle through which the shaft is twisted. With Mr. Gibson's meter it is possible—and also, to a lesser extent, with some other systems—to pick up the average angle of torque with fair accuracy, but the only auto-

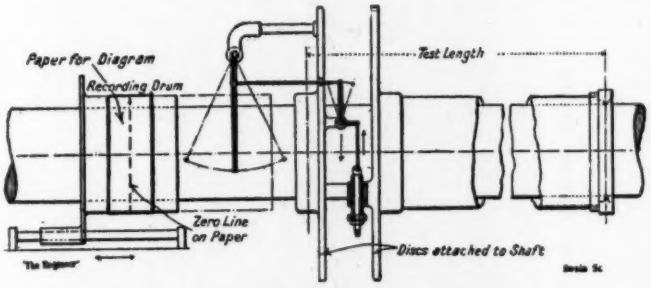


Fig. 2.—PRINCIPLE OF FÖTTINGER'S TORSION METER.

matic-recording meter which has been evolved is that brought out by Dr. Föttinger, of the Vulkan Company. The system of surrounding the shaft by two concentric tubes fastened to it at their extreme ends, and measuring the angular displacement at the periphery of the disc carried by the tubes at their inner and free ends, was introduced first by Föttinger and copied by various other inventors. Föttinger went further, and arranged a pencil attachment after the nature of an ordinary indicator motion that reproduced in the usual way a line corresponding to the forces affecting it, or, more correctly, the actual—or enlarged, according to a known scale—angular

displacement of the two discs, from which, knowing the modulus of the shaft, the force tending to cause this displacement could be calculated. Diagrams could thereby be obtained that showed the relative angular displacement of any two points on

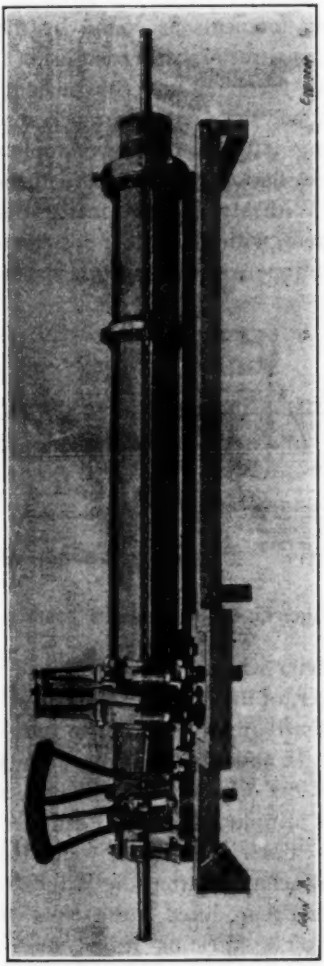


Fig. 3.—Torsion Meter on Cruiser "Lubeck."

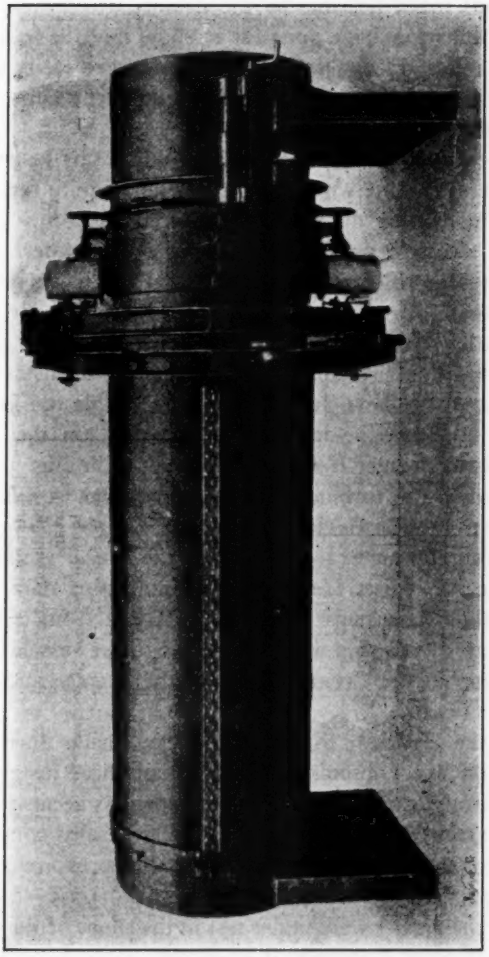


Fig. 4.—Torsion Meter on S. S. "Kaiser Wilhelm II."

the shaft during one complete revolution. When carefully analyzed in conjunction with the twisting-moment curves as given by the indicator diagrams, various points of considerable importance in the design not only of shafting, but of engine arrangements as well, were elucidated, and the more accurate

investigations made possible by the definite determination of mechanical efficiency have gone far to show that the balancing troubles of ten years ago would have been more easily solved if actual instead of theoretical twisting-moment curves had been available.

It required little further ingenuity to adapt this instrument to the needs of turbine work which does not require recording meters. The angular displacement for constant torque can be utilized by means of small levers to work a pointer over a graduated scale, which is so arranged that the movement can easily be read off. In both types the indicator drum or scale is fixed, so that facility of operation is assured. Fig. 2 shows the system in principle, while Figs. 4 and 3 illustrate two types of meter that have been put to considerable use in practice. Fig. 4 shows the meter that was used on the Norddeutsche Lloyd steamer *Kaiser Wilhelm II,* while Fig. 3 shows that adopted in the turbine cruiser *Lubeck,* and is similar to that used in the Curtis turbine vessels *Kaiser, Creole* and *Salem.* A similar meter to that used in the *Kaiser Wilhelm II* was used on the cruiser *Hamburg,* and interesting data, about which we shall have more to say, is available from the comparative trials of this ship with the *Lubeck,* these vessels closely corresponding in the German Navy to the *Topaze* and *Amethyst* in our own.

One of the criticisms of torsion meters made during the discussion on Mr. Gibson's paper was that these instruments have been brought into wide use and accepted as accurate without any standardization test such as is generally considered necessary for the instruments of precision, as pressure gauges, chronometers, etc. During the time—May, 1905—that the turbines of the *Kaiser* were under test in the shops of the Allgemeine Elektrizitats Gesellschaft of Berlin, a series of careful trials were made to check the "pointer" type of meter shown in Fig. 3 against the water brake used to produce the load for these turbines. The results show a very close accordance, and are given in Table 1 :

Number of trial.	Hours duration.	Number of readings.	Horse-power found by brakes.	Horse-power found by meter.	Difference of H.P. given by meter and brake, per cent.
1	1	12	2,778	2,786	0.29
2	1	12	2,776	2,778	0.07
3	1	6	2,773	2,773	0.00
4	1	6	2,767	2,766	0.04
5	1	6	2,771	2,768	0.11
6	1	6	2,761	2,762	0.04

Mean difference, 0.041 per cent.

The revolutions on the above trial were about 520 per minute. It is at least fair to assume from the above very considerable accuracy for well-designed and well-made meters.

The Bevis-Gibson meter, which has also been widely used, is radically different from any other, the method of measuring the amount of twist by the reflection of a beam of light and of

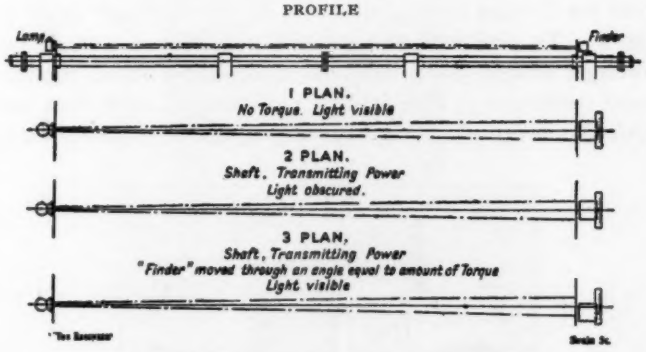


Fig. 5.—PRINCIPLE OF BEVIS-GIBSON METER.

finding the angle of displacement by means of the "torque finder" being distinctly original. The apparatus was fully described in Mr. Gibson's paper to the Institution of Naval Architects in 1907, and need not be described in detail; the principle is fully shown in Fig. 5. Fig. 6 shows the slotted disc attached to the shaft, with the eye-piece for picking up the longitudinal beam of light and the magnifying scale which

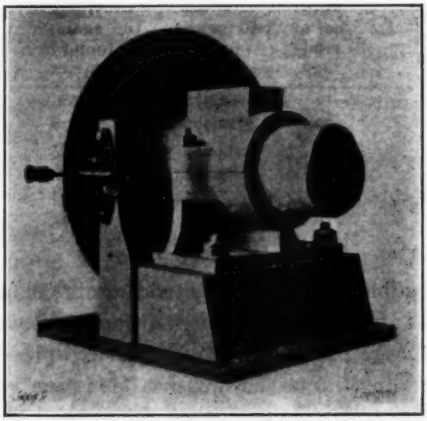


Fig. 6.—Disc on Shaft.

form the "torque finder," which is shown in greater detail in Fig. 7. To deal with reciprocating-engine work, where, as Föttinger proved, and Gibson has since corroborated, the torsional oscillation of the shaft is considerable, more than one reading is necessary in each revolution, and the Gibson meter

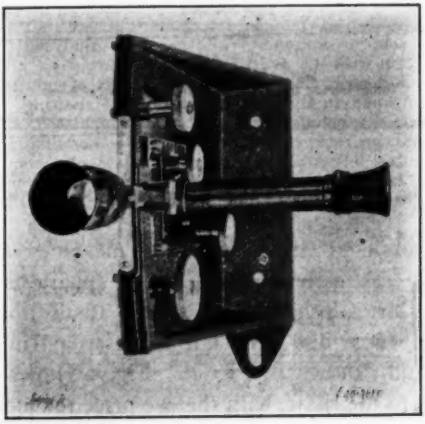


Fig. 7.—Eye Piece on Torque Finder.

is consequently provided with a special multiple-slot lamp shown in Fig. 8. The axial reader of the "torque finder" can be correspondingly moved in so as to read through the multiple slots in the displaced disc. These slots are set at varying radii, and at 30 degrees from one another, and afford a ready means of getting numerous readings at varying points in a revolution.

Another type of meter brought out by Professor Hopkinson, of Cambridge, was used to determine the shaft horsepowers

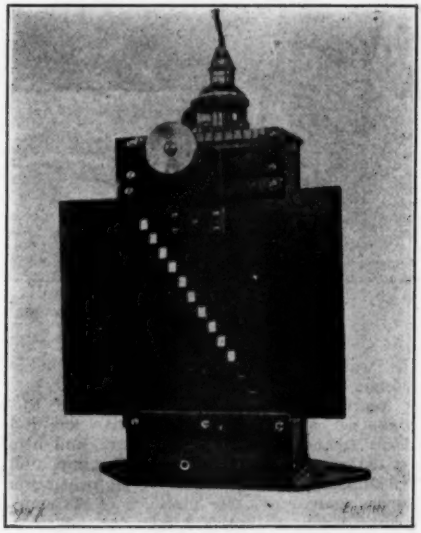


Fig. 8.—MULTIPLE SLOT LAMP.

on the ocean-going destroyer *Tartar*. With discs arranged as in the Föttinger indicator, the angular displacement is used to deflect a small mirror, the degree of which is measured on a scale engraved on a ground glass illuminated from outside by the same lamp whose beams are deflected on to the scale. A similar meter to this, brought out by Herr Frahm, of Hamburg, was used in conjunction with the well-known Denny-Johnson meter on the trials of the *Lusitania*. Fig. 9 shows the

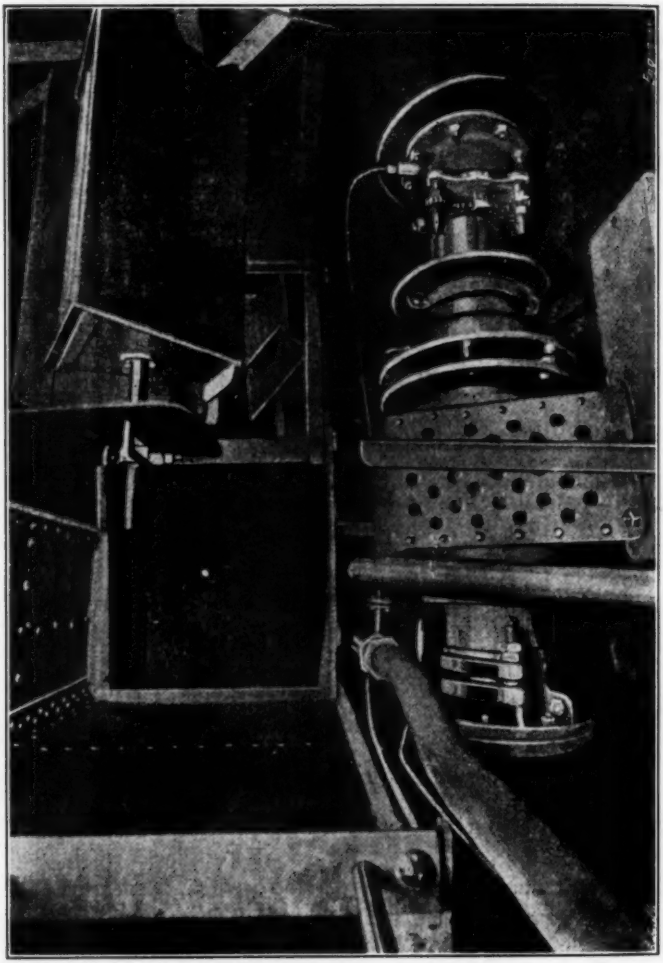


Fig. 9.—Hopkinson Meter on H. M. S. "Tartar."

Hopkinson meter fitted in the gland compartment of the *Tartar*.

Both in the case of reciprocating and turbine shafts the meter must be very carefully adjusted for its zero point or position where the shaft is absolutely free from torque. Mr. Gibson's meter is sufficiently sensitive to measure to 0.01 of a degree in commercial work; in fact, on the trials of the *Marylebone* he got as low a reading as 9.2 horsepower off a 2,600 horsepower low-pressure turbine at 24.4 revolutions, so that a slight error in initially fixing the meter will cause considerable error in the result.

Another important matter is the calibration of the shafting for determining the modulus of rigidity. Up to the elastic limit the angular distortion of a circular shaft bears a constant relation to the twisting moment applied, and this is expressed by the following formulæ:

$$C = \frac{12F \times 12L}{I_a \times \theta}, \text{ and}$$

$$F = \frac{C \times I_a \times \theta}{144L}.$$

C is the coefficient of rigidity in pounds per square inch, and up to the elastic limit is a constant for the shaft under consideration. F is the turning moment in the shaft in foot-pounds. θ is the angular distortion in circular measure between the two points on the shaft which were originally in the same straight line parallel to the shaft axis and distant L feet from one another. The geometrical moment of inertia of the shaft cross-section in inch units, I_a, can be calculated from the shaft dimensions, and equals $\frac{\pi}{32}(d_1^4 - d_2^4)$ where d_1 and d_2 are respectively the external and internal diameters of the shaft. If the shaft is a solid one, d_2, of course, is equal to 0, and $I_a = \frac{\pi}{32} d_1^4$. If we are in the position of being able to measure the extent of the angular distortion, then, knowing the coefficient C either from actual measurement or by taking a figure

known by experience to be a very close approximation for the class of material in question, we can deduce the value of F required to effect this distortion. The horsepower is given by the formula:

$$\text{H.P.} = \frac{2\pi N}{33{,}000} \times \frac{C i_a \theta}{144 L}.$$

Where no more accurate determination has been specially made, C may be taken at 11,700,000 pounds per square inch.

In nearly all cases it is the custom to ascertain the resistance to rotation of the shafting when disconnected from the engine by suspending weights at a known radius on the propeller blades when the vessel is in drydock, and from these observations the losses due to bearing friction can be closely calculated. This loss must be added to those of the engine before the actual power delivered to the propeller can be found. The system of suspending weights to make the shaft move enables two figures to be ascertained—(1) the amount required to start the shaft from rest, and (2) the amount needed to keep it moving, which is always less than (1) and more accurately represents the friction while at work. In many cases it is not strictly correct to assume the friction in dock to be the same as when the vessel is afloat in either light or loaded conditions, but it is necessary to do so for the purpose of converting these weight measurements into power, which can be done by multiplying the speed of rotation at a given power by the moment deduced from the recorded weight and radius. The resultant varies considerably between 1 per cent. and 4½ per cent., though about 2½ per cent. happens to be a very fair average for naval reciprocating work. Consequently, if, as was recently the case in a large intermediate liner, the engine efficiency as measured by $\frac{\text{B.H.P.}}{\text{I.H.P.}} = 91.7$ per cent., the actual power delivered to the propeller is only $91.7 - 2.5 = 89.2$ per cent.

To complete our list of torsion meters in wide commercial use, we give in Figs. 10 and 11 a diagram of the usual Denny-Johnson type of meter and a view of the recording box, and in

Fig. 12 a more elaborate diagram showing the wiring system adopted for this meter in the case of the scout cruiser *Chester* of the United States Navy.

Fig. 13 shows a recent form of the Hopkinson type of meter, with the double mirror giving readings both when approaching and leaving the scale. Numerous other forms of meter have been tried and many of them discarded on account of mechanical inferiority, difficulty of application or inherent

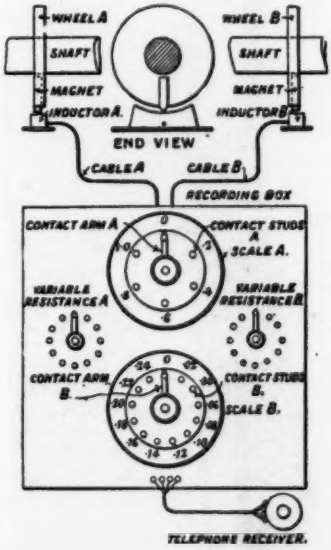


Fig 10.—Diagram of D.-J. Connections.

inaccuracy. One great stumbling block lies in obtaining exactly the zero position of the shaft for no torque. Among the various more experimental types may be mentioned those of Collie, Aimsler, Gardner, Thaemar and various others, none of which have been widely tried.

The calibration in the shop of the shafting on which the torsion meter is to be placed should be done with the greatest care. The system employed by Mr. Gibson and illustrated in

his paper is shown in Fig. 14; that adopted by Föttinger for the shafting of the German cruisers was tested in the manner shown in Fig. 15. The system of measuring the deflection of two pointers at known distances apart is simple enough, but

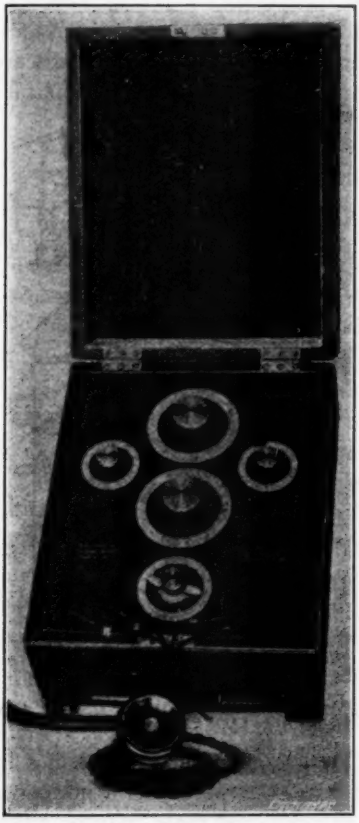


Fig. 11.—DENNY-JOHNSON RECORDING BOX.

it is by no means certain that it is a sufficiently accurate method of calibrating propeller shafting, which while at work is subjected to a very considerable end thrust. Mr. Gibson's method, therefore, introduces a hydraulic jack whereby an end thrust

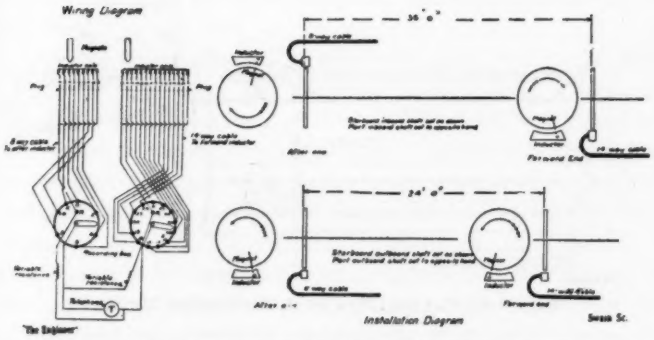


Fig. 12.—CONNECTION OF DENNY-JOHNSON METER ON U. S. CRUISER "CHESTER."

corresponding to that of the propeller it is intended to drive is put on the shaft, and which is found to increase the torque by some 3 or 4 per cent. in the case of hollow shafts. However accurate the dimension and homogeneous the material of propeller shafts, slight discrepancies in the modulus of rigidity

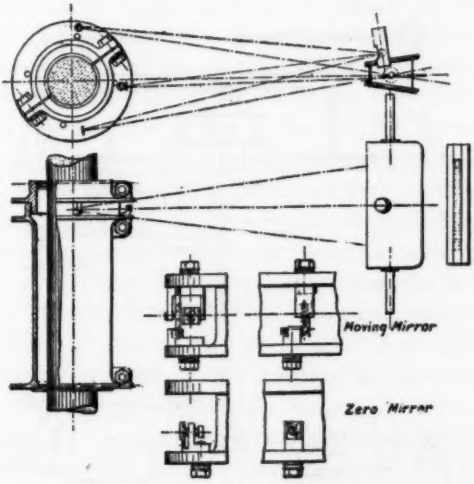


Fig. 13.—HOPKINSON METER.

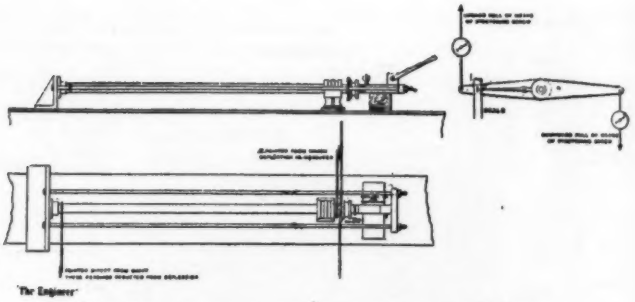


Fig. 14.—Calibration of Bevis-Gibson Meter.

of shafting always occur, just as there are slight differences even in apparently identical sets of springs, and this necessitates not only calibration in the beginning, but suggests the advisability of periodical recalibration. Some years ago when Herr Frahm was engaged in his experiments on vibration and the torsional stresses in shafting, a series of steel shafts, made by various German firms, were calibrated at the Royal Mechanical Testing Department at Charlottenburg, and these showed a

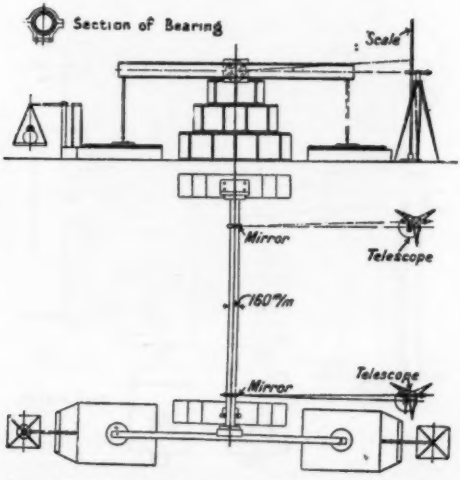


Fig. 15.—Calibration of Föttinger Meter.

slight difference in shear modulus, amounting, however, to less than 1½ per cent.

For the calibration in the shop, the fixed end of the shaft should be most accurately fastened; there is often a tendency for the securing bolts and plates to give as the load comes on. The effect on the deflection readings of increasing the load up to the maximum and then similarly reducing it is to give two different sets of curves, the latter method giving a lower modulus than the former. If the shaft be maintained in a live condition by tapping it with hammers the irregularities of modulus observed under purely static conditions largely disappear, and this condition undoubtedly more nearly represents that found in service. Completing this by the addition of end thrust shows how materially the torque varies under this condition.

The Denny instrument depends for its accuracy on the aural faculties of the user. The torsion of the shaft causes the zero winding of the inductor A—see Fig. 10—which is nearest the engine or turbine to be excited in advance of the other by the amount of the angular displacement of the shaft, and a loud ticking sound can then be heard in the receiver as the currents induced in each inductor no longer neutralize one another. The contact arm—see Fig. 10—is then shifted from stud to stud until the position of greatest silence in the receiver is obtained, and when this position is found, the reading on the scale B opposite the contact arm represents the circumferential measurements of the angle of torsion of the shaft at the radius of the indicator windings. Silence in the telephone is occasioned by the fact that through the contact arm B, which is in connection with inductor B, at the same instant as a current is induced in the zero winding of A, a current equal in strength is also induced in that winding of inductor B, so that the scale reading exactly represents the angular displacement of one magnet relative to the other while the two currents neutralize the effect on the telephone receiver. At very low power it has sometimes been found hard to hear this meter, and the leading of the telephone wires up to a quiet cabin in which the record-

ing meters are also placed is a necessity as well as an advantage. In the case of the Föttinger meter shown in Fig. 3 the relative angular movement on the shaft surface is communicated to the pointer, which works over a carefully graduated scale. In this, as in all torsion meters of the purely geared mechanical type, it is impossible to avoid a certain amount of "stagger," but the scale is easily arranged so that one-sixteenth inch represents 50 horsepower. When running against a brake on a solid foundation the pointer is extremely steady, but there is always some vibration in shaft alleys on board ship.

In the type of meter shown in Fig. 4 we get what is at present the most suitable type of recording meter yet devised. In this case diagrams are taken with ease and accuracy, and the value of the data gained is very great. The circumferential velocity of the drums bearing the paper, which are driven by the toothed wheel shown on the right-hand side of the meter, is between 11 feet and 12 feet per second, and this necessitates great care in allowing for all the effects of centrifugal action on the pencil and on the drums in the design. The sleeve bearing the drums and gear for driving them can be put out of gear and run back by the handle and screw shown on the extreme right of Fig. 4, and the paper removed and replaced. The length of shaft on which this meter was used on the *Kaiser Wilhelm II* was 63 inches, the shaft diameter being 23½ inches. The indicator-paper drum was 4½ inches diameter, and the length of diagram for one complete revolution about 13½ inches. Obviously this type of meter costs more to make than non-recording types, but the advantages of obtaining a definite record as opposed to a snap reading at any point in the revolution is very considerable.

This essay was commented upon by Mr. Gibson as follows:

THE EFFICIENCY OF MARINE ENGINES AND PROPELLERS.

By Mr. J. Hamilton Gibson.

Your interesting articles on the "Mechanical Efficiency of Marine Engines" suggest a few observations.

In all torsionmeter records it is of the first importance to

calibrate the length of shafting that is to be used by actual experiment in the shops. If two or more lengths of shaft are to be used, they should be rigidly coupled up with their own bolts and the recording pointers attached at the exact positions of the torsionmeter discs.

A simple length of apparently high-grade steel shaft will show a different modulus of rigidity at each end. The tensile and elongation tests of the material are no guide to the rigidity factor, as will be seen by the following results obtained from four identical shafts, 9 inches diameter:

Modulus from torsion.	U. T. S.	Elongation in two inches.
12,470,000	35.08 tons	33 per cent.
12,470,000	31.33 tons	38 per cent.
12,110,000	33.66 tons	32 per cent.
12,160,000	33.92 tons	32 per cent.

The variation of the modulus of rigidity of apparently identical shafts may range from 11,500,000 to 12,500,000, which involves an error of nearly 9 per cent. in arriving at the shaft horsepower. Indeed, it is not altogether an unknown expedient, in cases where there are no reliable calibration records to appeal to, to alter the modulus constant to suit the expected power. The shipbuilder element naturally wishes to see a low power for a given speed and displacement, and the alteration of the modulus of rigidity of the shafting offers a ready means of "cooking" the results.

I quite agree that shafts should be periodically re-calibrated if possible, and I should expect to find a slight reduction in the rigidity of a shaft after two or three years' constant use. The reduction would probably be greater in reciprocating jobs than with turbine-propelled vessels, on account of the greater variation of torque in the former. On the other hand, the stresses of intermediate lengths of shafting are so well within the elastic limit that the alteration of rigidity may prove to be so slight as to be practically negligible. But this point can only be settled by actual demonstration, and no doubt our British Ad-

miralty authorities will be in possession of the required information before very long.

The possible variation in torque of turbine-driven propeller shafting is a matter that has suggested itself to more than one investigator. Mr. Thring, in the discussion on my torsionmeter paper at Newcastle, stated that the result of his observations with a "Hopkinson-Thring" meter on a 33-knot destroyer showed a maximum variation of only 3 per cent. on one of the wing shafts; but this may well be due to the slight pitching of a vessel in a moderate sea. I fitted a reciprocating-type flash-light torsionmeter on an inner shaft of a four-shaft destroyer, expecting to find some variation due to interference of the forward wing propeller, with the result that the readings came out practically identical.

Generally speaking, I should say that a turbine-driven shaft experiences no appreciable fluctuation of torque, and that a single reading at one point of the revolution is all that is necessary. The practice in taking flash-light torsionmeter readings is for two observers to take readings one after the other as quickly as possible—one watching the flash at the eye piece and manipulating the micrometer screws, the other reading the scale through the microscope to prevent collusion. Any slight difference in the reading is noted, and can be invariably traced to its source. Sometimes it is a momentary difference in steam pressure or vacuum; or the vessel may have altered her course; or a different depth of water may have retarded or accelerated the revolutions, and consequently changed the torque. All these conditions are instantly noticed at the torque finder, and have frequently led to anxious inquiries from the observers down below at the shafts, who, of course, are not aware of any change of conditions having taken place.

As the disappearing flash is noted just at the point of cut-off in taking readings, it early occurred to me that if there was any torsional oscillation in the shaft we were probably only catching the crests of such oscillations, and I then arranged to take readings from both edges of the slots to arrive at a true mean. This also, as you have observed, eliminates the personal equa-

tion of good *versus* indifferent eyesight. But a careful comparison of results over a long series showed no appreciable difference between extreme and mean readings, and this I think corroborates the view that the torque of turbine-driven shafting is remarkably steady and constant.

The question of obtaining a visible automatic record has engaged my attention, and photographic or pencil records can be taken at the flash-light torque finder; but with such minute differences as 1/500 inch to contend with, there is nothing to equal direct vision. Certainly, a continuous record of the Föttinger or Edgcumbe type is an ideal result to aim for; but for turbine work, at any rate, I have come to the conclusion that the direct method is the simplest and most accurate.

The verification of exact zeros at the beginning of every trial is very advisable in dealing with such minute measurements, as one never knows whether the discs may not have been shifted since the last trial; and even though the lamp and torque finder fit into dowelled recesses, the brackets to which they are attached, being generally of a temporary nature, may have become displaced.

The best way to obtain zeros is to shut off one turbine at a time, and to let the others maintain the way of the vessel. The idle propeller will then revolve its turbine and shafting up to nearly the full revolutions. Great care should be observed to ensure that the idle turbine is revolving in a vacuum.

In checking zeros after a prolonged trial, I once found a difference .06 of a degree on a low-pressure shaft, which turned out to be due to an auxiliary exhaust, led into the low-pressure receiver, having been left open.

For reciproçating engines, of course, there is nothing for it but to disconnect the propeller, and revolve the shafting by the engines, trusting to the discs remaining untouched during the process of recoupling.

There is one aspect of the problem of the mechanical efficiency of marine engines about which I may be permitted to add some remarks. Besides the terms "nominal horsepower," "indicated horsepower," and "shaft horsepower," we now have

"equivalent indicated horsepower," "legend horsepower," "effective horsepower," and so on. Many people are puzzled when they hear that the "shaft horsepower" of a turbine vessel is so much in excess of the original estimated "indicated horsepower." Identical vessels with equal boiler power, but one driven by reciprocating engines and the other by turbines, will show 15 per cent. to 20 per cent. excess of power in the latter over the former for the same speed.

The first impulse was to discredit torsionmeter results; but it is now recognized that the difference is due almost entirely to propeller efficiency. And therefore I should like to add another term to the list, and call it "thrust horsepower," although this is merely another name for "effective horsepower" —that is, the power available to propel the vessel when the inefficiency of the propeller is deducted. In dealing with the efficiency of a marine engine, I take it we cannot dissociate the boiler and the propeller, as they form essential parts of the propelling machine.

Let us take two diagrams, Fig 1, which will aid in fixing our ideas:—A and B represent the machinery of two sister

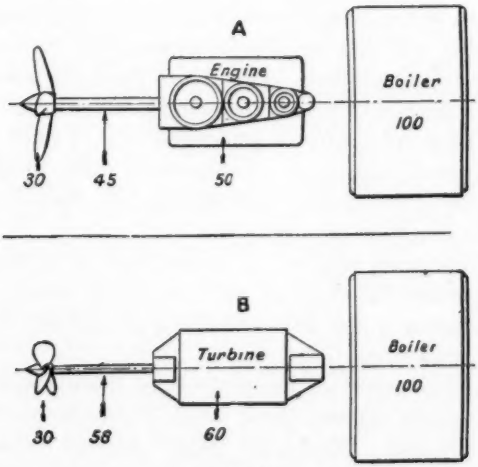


Fig. 1.

vessels which are to be driven at the same speed. The boilers are similar, and each generates 100 units of power; but A is a reciprocating job doing 150 revolutions per minute and B a turbine vessel of 600 revolutions per minute.

If the reciprocating engine can indicate 50 power units with a steam consumption of 18 pounds per indicated horsepower, then the turbine, assuming it could be indicated, would show 60 units at 15 pounds. The frictional losses in A are responsible for only 45 units appearing at the shaft, whilst the superior frictional efficiency of the turbine gives 58 shaft units in the case of B.

If the two vessels make the same speed, we may take it that the thrust of the propeller shafts are equal in both cases, and that the total efficiency of installation A is equal to that of B. Assuming, then, 66.6 per cent. propeller efficiency for A based on shaft horsepower, we arrive at 52 per cent. efficiency for B propeller on the same basis.

These comparative figures are fairly normal for the two types at 16 to 20 knots, and if multiplied by 100 show at a glance how it is that a turbine-propelled vessel of 5,000 "equivalent indicated horsepower"—that is to say the indicated horsepower of a reciprocating engine to propel the vessel at the same speed—will show 5,800 shaft horsepower by torsionmeter; an excess of 16 per cent.

The point that emerges in a comparison of this nature is the inefficiency of the small high-speed turbine-driven propeller, as compared with the large low-speed piston-driven screw; and suggests that the high-speed propeller offers ample scope for improvement.

What we should like to see would be a reliable thrust indicator that would enable us to ascertain the exact compression in the propeller shaft of a turbine compared with that of a reciprocating-engine shaft; but so far we have to rely for our propulsive coefficients and effective horsepowers on the results of tank experiments, which may or may not be reliable.

I have succeeded in obtaining indicator diagrams from the thrust block of a vessel propelled by reciprocating engines, and

the results were submitted in my reply to the discussion on the torsionmeter paper referred to; but I am not aware of any similar data having been obtained from a turbine-propelled vessel.

Is it possible that the present evolution of high-speed and high-power propellers is proceeding on wrong lines? It is evident from recent trials that diameter, pitch and slip have little to do with turbine-propeller efficiency; but sufficient projected area matters a great deal. So long as the maximum thrust along the shaft for a given power can be achieved, the exact shape and proportions of the propeller and the number of revolutions may be neglected. Certain improved perfor-

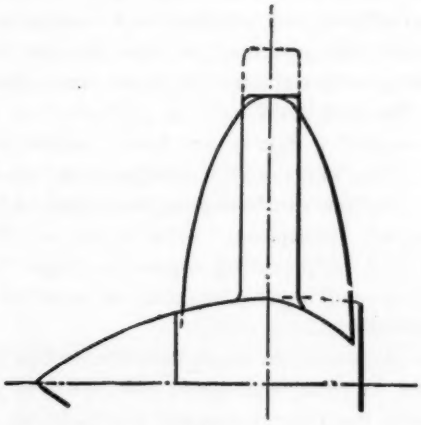


Fig. 2.

mances have been obtained by ringing the changes between three and four-bladed propellers. Has it occurred to anyone to try the effect of a dozen blades? The old-fashioned four-sailed windmill was a favorite analogy for the large slow-speed four-bladed marine propeller, which is undoubtedly very efficient for comparatively low-powered vessels.

But a multiple-vaned windmill revolving at a high speed is now the vogue, and we may further instance the motor-driven

"Sirocco" fan and the many-vaned water turbine driving the high-powered dynamos at Niagara.

The abnormally broad blades of three-bladed turbine propellers of 70 to 80 per cent. surface ratio present a large profile area in the direction of revolution, and mysterious deep corrosion has been experienced at the roots supposed to be due to oxidizing gases liberated or generated by the maelstrom churned up near the boss. A twelve-bladed propeller would present only one-fourth of the profile area of a three-bladed propeller of the same projected area, and could be revolved at a correspondingly increased speed for the same power. Or, conversely, the diameter, and therefore the projected area, could be increased—as shown by the dotted tip, Fig. 2—for the same power and revolutions, which would appear to be a step in the right direction.

But until some enterprising firm lays down a plant for testing actual full-sized propellers by running them in water at the designed power and revolutions, and registering the thrust produced, we must be content to accumulate data from trial-trip results, and do our best in designing new propellers to meet new conditions.

I trust, however, that this contribution to your admirable series of articles will be fruitful in suggestion, and that in dealing with the subject of the "Mechanical Efficiency of Marine Engines" the claims of the propeller problem will not be overlooked.—"The Engineer."

In the case of the Gibson meter, the operation of taking readings off a shaft is particularly simple. The observer watches the beam of light either at one point of a revolution in a turbine vessel or at twelve points consecutively in a reciprocating job, through an axially-arranged telescope that has to be moved circumferentially on a graduated scale concentric with the shaft. A small magnifying glass is also fitted—a view of the complete eye-piece and torque finder was given in Fig. 7 to enable the scale to be easily read, and there is no difficulty whatever in taking observations to a hundredth of a degree.

As the deflection in 10 feet for normal stresses in shafting is about one degree, regardless of shaft diameter, and the length generally available for readings about twenty feet, it is obvious that a very considerable degree of accuracy can be obtained. A further advantage lies in the fact that double readings can be taken with the Gibson meter by using the two edges of the slot in the torque-finding disc alternately, and thereby arriving at the mean reading and enabling any possible error due to the personal element to be neutralized entirely.

Rays of light travel in absolutely straight lines through air of even density, and as the velocity of light is practically infinite, Mr. Gibson's method of reading by moving his torque finder first one way and then the other until the light is just disappearing off the edge of the slot must obviously be one of great accuracy. The Gibson type of radial meter is shown in Fig. 16.

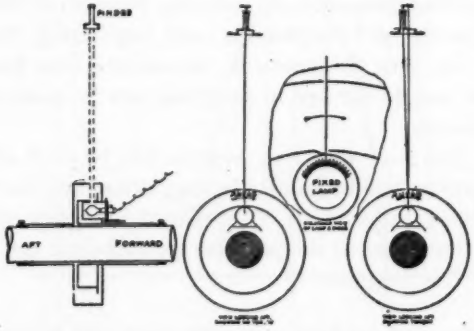


Fig. 16.—GIBSON RADIAL METER.

In the Hopkinson meter, as with that of the Denny type, it is only possible to get readings at one or two isolated spots in each revolution. The meter is based on the usual relative angular movement of two discs which, in this case, are used to deflect a small mirror pivoted between them. An electric light set on the zero position of the scale enables the mirror to reflect the rays of light into a graduated scale at a known distance off which the angular deflection can be read. In the

case of one or two turbine vessels it has been found that the ray has fluctuated across about 4 or 5 per cent. of the number of divisions recorded on the scale at full power, but it was found to be quite simple to read off the mean position. A much more serious objection to the practical use of this meter is the possibility of the mirror becoming blurred with steam or grease, though in many cases it is possible to arange it well clear of the engine room. This type of meter, together with the Denny instrument, was used on the recent trials of H.M.S. *Inflexible*. Centrifugal action is apt to affect the readings on nearly all types except the flashlight meter, and the accuracy can never be regarded as above suspicion when complicated gearing and single observations per revolution are concerned. Recording meters are impossible without gearing unfortunately, but they possess compensating advantages. Where possible, all shafting should be calibrated, and the meter calibrated also against a water brake. Exceptional accuracy of workmanship is required in the construction, and provision for adequate fastening to the shaft should be made to obviate any possibility of the discs shifting during a trial. Rigidity is also essential, and in all cases guards should be placed over and round the meters to obviate damage either to the meter or to the observers.

Prior to the commencement of each trial it is usual to run the shaft at a very low speed in order to obtain the zero position. This has not been properly done in one or two cases, and the resultant horsepower readings have been absurd. The best way is to run the shaft first one way and then the other in order to arrive at the position of no torque. Some meters are greatly superior to others in this respect, as they carry a standard attachment whereby the zero position is indicated constantly, and the deflection can always be referred to that point.

In other cases the engines are run up to full speed, steam is then shut off and the ship allowed to come gradually to rest. The way on the ship will cause the shafts to run with practically no torque, and the point can easily be found on the torsion meter.

It has frequently occurred that torsion meters of different

types have been applied to the same shafts. In the *Lusitania* a Frahm meter—a type identical with Hopkinson's—was checked against one of the Denny-Johnson type; in the *Heliopolis* and *Cairo* Denny-Johnson and Bevis-Gibson meters were used. These cases, among others, have both shown that the instruments checked one another fairly well, but there is nevertheless a feeling which is growing rapidly in some quarters to the effect that in some cases there have been some very erratic readings and false deductions from meters.—"The Engineer."

PRACTICAL OIL ECONOMY OF THE U. S. S. *RHODE ISLAND.*

By M. S. Holloway, Machinist, U. S. N.

Note.—The remarkable oil economy of the *Rhode Island* during the cruise around the world has attracted much favorable comment. The oil consumption of this vessel was very materially lower than that of the other vessels. This example shows the possibilities of the proper use of competition to secure good engineering results. It is hoped that the practice of having engineering competition may be continued, and also extended to a broader field, so as to include in general all the work of the engineer force, including the economy of repairs and use of supplies and the improvements and repairs effected by the ship's force.

As a result of the contest in steaming efficiency among vessels of the Atlantic Fleet during the recent cruise the keenest interest was awakened among officers and men of the engineering personnel, and many ideas were worked out for the saving of coal, oil and wear of machinery.

The economical oil expenditure of the U. S. S. *Rhode Island,* while chiefly due to careful attention in the engine room, may also be attributed to the following conditions:

First. Favorable arrangement of oil tanks.

Second. Installation of oil manifolds of improved design.

Third. Conservative adjustment of journals.

ARRANGEMENT.

The *Rhode Island* is fitted with four (4) lubricating oil tanks in each engine room, aggregating a capacity of 2,936 gallons. From these tanks suction pipes are led through filtering tanks to small hand pumps on the lower platform, from which the supply is pumped into two gravity tanks, each of 40 gallons' capacity, located at an elevation from which the oil will readily flow to all manifolds through piping specially arranged for filling purposes. All tanks are fitted with gauge glasses, behind which are fitted brass plates graduated in a scale of gallons, the gravity tanks being more finely graduated for closer accuracy in logging the exact amount of oil used by each watch.

The manifold boxes are of the cast-brass type installed at the New York Navy Yard, as illustrated, and are very similar to those installed on the U. S. S. *Connecticut.*

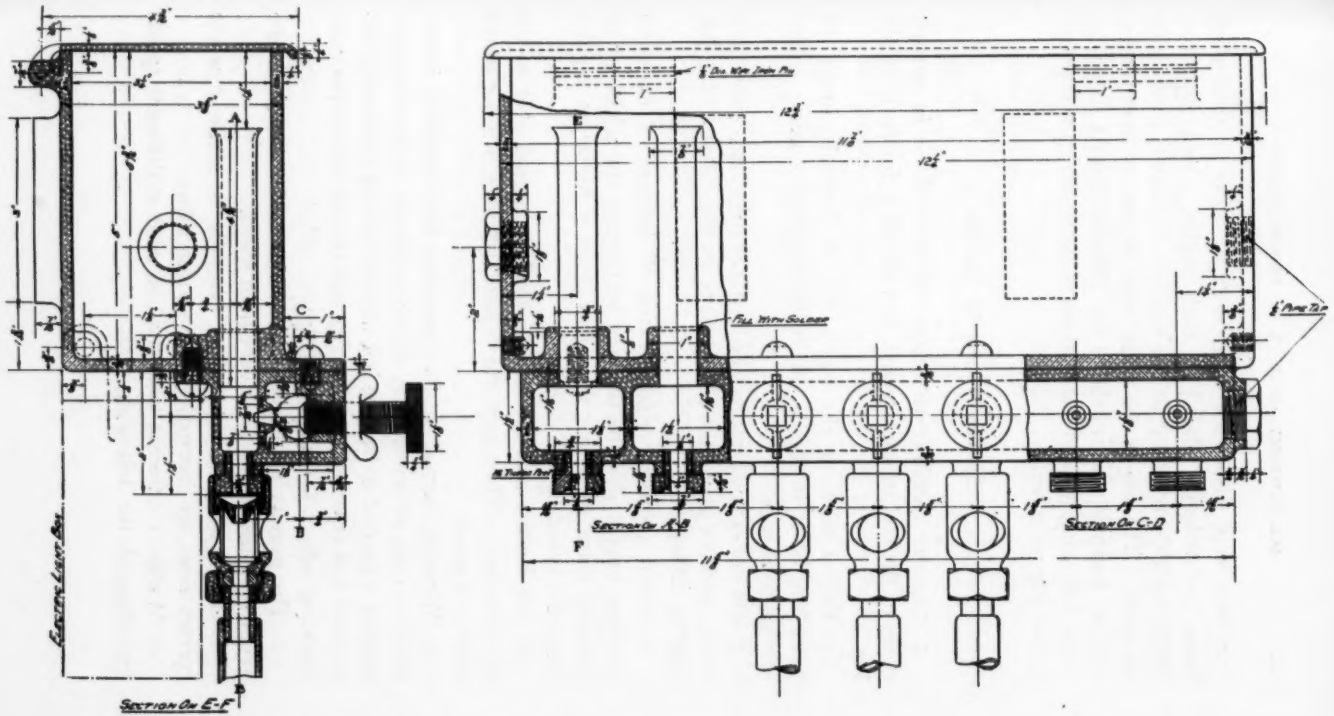
The main reservoir is of ample size, containing ⅝-inch tubes, through which oil is syphoned by the usual worsted syphon wicks. To the base of these boxes are fitted separate gravity manifolds having valve connections to a common discharge from each syphon tube. Separate supply connections are made to the syphon boxes and gravity manifolds by which either may be filled and used independently when desired.

Electric lighting boxes are also fitted behind each manifold to illuminate the sight-feed glasses.

MANAGEMENT.

When nearly empty the gravity tanks are filled by the watch going off duty, each watch entering in the log the amount of oil used and the amount remaining, by which method the various watches may have access to the record of oil consumption.

Experiments were made to determine the minimum strands of worsted yarn necessary to form wicks of required size for steaming at different rates of speed. A supply of wicks of all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sizes was kept suspended upon rows of wires in dust-proof boxes conveniently placed in each engine room, each row being marked according to the number of strands comprising the wick. The use of the wicks with respect to sizes for the various journals was regulated for different speeds, as shown in the following printed instructions to oilers, which was posted in the engine room.

INSTRUCTIONS TO OILERS.

1. Observe carefully the exact amount of oil in gravity tanks at the end of each watch, and report it for entry in the log.

2. Before relieving the watch feel all journals, insert the hand into holes in caps of main bearings and observe water-service discharge.

3. Oil boxes shall not be filled oftener than once every four hours, and not above the filling mark on the inside. Not that high if rolling.

4. When journals require extra oil because of excessive working heat it shall be supplied by dipping the wicks, or by pouring extra oil down the tubes from a feeder at regular intervals, noted by the clock.

5. Oil feeders and squirt cans shall be turned over to the relief empty. When cans are injured report it at once to the officer on watch.

6. When a journal shows increasing heat report it immediately to the officer or petty officer in charge. Any oiler permitting a journal to become hot without having previously discovered and reported it as heating will be reported to the commanding officer for neglect of duty.

7. The gravity manifolds will not be used except in emergency or when steaming at very high speed.

8. Oilers will examine wicks carefully to make sure the correct sizes are inserted in the proper tubes.

9. Wicks of different sizes shall be used at different speeds according to the following table:

Revolutions per minute.	Size of wicks, in strands.						Number wicks to each journal.
	60	66	72	78	84	90	
Link gibs	2	2	3	3	4	4	1
Link block pins	2	2	3	3	4	4	1
Yoke guides	2	2	2	3	3	3	1
Suspension rods	2	2	2	2	2	2	1
Eccentric rods	2	2	2	3	3	3	1
Crosshead brasses	4	5	6	7	8	9	1
Ahead slides	5	6	7	8	9	10	1
Astern slides	2	2	2	2	2	2	1
Crank pins	5	6	7	8	9	10	2
Eccentric straps	4	4	6	6	8	8	1
Main journals	3	3	4	4	6	6	4
Spring bearings	3	3	3	4	4	4	3
Air-pump tubes	2	2	2	3	3	3	1
Circulating-engine tubes	2	2	2	3	3	3	1

The size of wicks necessary for different rates of speed, as shown above, was determined after considerable experimenting, and the table in the above instructions to oilers changed from time to time as deemed advisable.

The following record of oil expenditure for the cruise is taken from the official report on this subject:

Lubricating-Oil Expenditure, U. S. S. Rhode Island, Dec. 16, 1907–Feb. 22, 1909.

At sea.	Gallons used.	Miles.	Miles per gal.
Hampton Roads to Trinidad	344	1,751	5.1
Trinidad to Rio de Janeiro	658	3,191	4.7
Rio de Janeiro to Punta Arenas	209	2,230	10.6
Punta Arenas to Callao	313	2,857	9.1
Callao to Magdalena Bay	236	3,038	12.8
Target practice, Magdalena Bay	60	385	6.4
Magdalena Bay to San Diego	50	591	11.8
San Diego to Long Beach	12	100	8.
Long Beach to Santa Barbara	7	6	.8
Santa Barbara to Monterey	24	223	9.2
Monterey to Santa Cruz	4	26	6.5
Santa Cruz to San Francisco	16	98	5.3
San Francisco to Bellingham	136	866	6.3

At sea.	Gallons used.	Miles.	Miles per gal.
Bellingham to Seattle	14	85	6.
Seattle to Tacoma	6	24	4.
Tacoma to Bremerton	7	26	3.7
Bremerton to San Francisco	255	821	*3.2
San Francisco to Honolulu	208	2,085	10.
Honolulu to Auckland	302	3,880	12.8
Auckland to Sydney	114	1,314	11.5
Sydney to Melbourne	75	623	8.9
Melbourne to Albany	124	1,361	10.9
Albany to Manila	351	3,486	9.9
Manila to Yokohama	178	1,799	10.1
Yokohama to Subig Bay	161	1,748	10.8
Subig Bay to Manila	15	52	3.4
Target practice, Manila	178	643	3.6
Manila to Colombo	153	2,926	19.7
Colombo to Suez	170	3,350	19.7
Suez to Port Said	12	85	6.8
Port Said to Marseilles	128	1,578	12.3
Marseilles to Gibraltar	47	690	14.6
Gibraltar to Hampton Roads	174	3,600	20.7
Total	4,736	45,544	

	Gals.
Oil used for steaming purposes	4,736
Oil used for auxiliary purposes, during 247 days in port	658
Total	5,394
Oil on hand December 16, 1907	2,959
Oil received during cruise	3,850
Total on hand and received	6,809
Oil on hand on February 22, 1909	1,415
	5,394
Average miles steamed per gallon during cruise	9.616

*Including 6 hours' run at three-fourths power.

It will be noted that the greatest expenditure per mile occurred on the shortest voyages. This is partly due to the policy of using oil liberally when getting under way and for the first watch at sea; also to the practice of draining oil boxes upon arrival in port for the purpose of cleaning them out.

Much of the oil thus removed was strained and used in the thrust-block reservoir, requiring new oil for refilling manifolds. The smallest expenditure per mile occurred during the last voyage, between Gibraltar and Hampton Roads, which voyage was made at the rate of 20.7 miles per gallon or about one half gallon per 100 I.H.P. per day.

It is the opinion of the writer, however, that so small an expenditure as that of the last voyage, or the voyage from Manila to Suez, is not one of economy in the broader sense. The minimum was reached through efforts prompted by the desire to excel in the contest, and while it is possible to reduce lubrication to the minimum upon which bearings will run without heating, it is also apparent that greater wear occurs than is the case where friction is reduced by more liberal lubrication. It is therefore considered that from 10 to 15 miles per gallon is a safe and economical expenditure when cruising at 10 or 12 knots per hour. This speed calls for 2,500 to 3,500 I.H.P.

The clearance allowed in the adjustment of bearings is a feature of first importance in connection with oil economy. Engineers who sleep better when all journals are adjusted so closely that no sound or jar may be detected to disturb their rest are usually not especially interested in economy of lubricant.

There are other engineers, however, who sleep even more soundly knowing their journals have sufficient room in which to breathe while at work, and whose dreams are not disturbed by the clang of the gong to slow and stop, the smell of burning oil and the sound of sledge blows "slacking back."

It is the practice on the *Rhode Island* to adjust the clearance in main engine journals as follows:

Crosshead brasses, No. 33 S.W.G., or 7/1000 inch.

Crosshead-slipper clearance, 5/1000 inch.

Crank-pin and main-journal brasses, No. 31 S.W.G., or 9/1000 inch.

This adjustment might be considered too coarse for some types of engine, depending upon the smoothness of running as influenced by design. With the well-balanced engines of the four-cylinder triple-expansion type, as installed in the battleships of our present fleet, no difficulty should be experienced from vibration with the above adjustment.

The equal distribution of work in the various cylinders, as influenced through proper adjustment of cut-off, is also a feature affecting lubrication as well as other points essential to economical engineering. With the H.P. crank performing twice the work of both L.P. cranks, or four times the work of one L.P. crank, the former will be found to require about six times as much lubrication as the latter, showing the ratio of increased lubrication to be more than double the increase of power.

The exact ratio of increased lubrication essential to increase of horsepower is a subject which we have little opportunity to determine, owing to the infrequency of steaming at full power for more than a few hours. The oil expenditure as shown upon builders' trials and acceptance trials is, indeed, a poor criterion, as the importance of final success becomes paramount to minor results. A good margin of safety in lubrication is, of course, a wise policy to follow when steaming at high power, but the old adage, "A man can get as wet in the rain barrel as in the ocean," is also applicable to marine-engine lubrication, and careful attention along these lines throughout the fleet will surely result in a saving of considerable consequence to the yearly running expenses.

NOTES.

SPECIAL NOTICE.

By direction of the Council, the following general schedule of prices to be paid for accepted original contributions published in the JOURNAL is given:

A minimum rate of one dollar per page of original matter is established. This price to be increased in proper proportion for matter of special interest and value, and special allowance will be made for original drawings, diagrams, special computations, illustrations, etc., the award for which will be made by the Council.

Attention is also invited to notice of conditions of award of prize essay under *Association Notes.*

Members are specially requested to bring the advisability of joining this Society to the attention of younger line officers interested in technical work in the Navy.

It is to be regretted that the membership includes but a very small proportion of the officers whose coöperation is desired and who would be greatly benefited by the aims and purposes of this Society.

It is not the purpose of the Society to confine its activities or the subject-matter of the JOURNAL to purely steam engineering, but instead to all naval subjects of a technical nature, this really being the broad scope of Naval Engineering. For this reason the coöperation of officers who are not, as well as those who are, doing engineering duty is earnestly desired.

The membership among the active officers of the Line and Construction Corps of the Navy and officers of the Revenue Cutter Service, compared with the total number of these officers, is comparatively small. If this number can be in-

creased to five or six hundred it is easy to see the increased influence and power for professional advancement of engineering that the Society will possess, and by such an increase the membership will become more valuable and the JOURNAL more potent in its influence for the distribution of engineering knowledge.

H. C. DINGER,
Secretary-Treasurer.

SURFACE OR SUBMARINE TORPEDO BOATS.

In the development of the various specialties contributing to the art of torpedo warfare we are brought face to face with a condition calling for pause and serious consideration. With typically modern endeavor to increase speed, not only in torpedo craft, but in the torpedo itself, the specialist in each direction has been working to a large extent blind to or unmindful of the changing relations which this common endeavor to attain speed has effected. The most singular part of this evolution is the fact that the torpedo has quite outstripped the fastest of surface craft so far as vessels of that sort serve as efficient or practicable bases for its discharge. In other words, because of conditions extraneous to the surface-torpedo vessel, these craft are really no longer able to make the most of what the automobile torpedo now offers as a means of attack.

Only a very few years ago the submarine—we make no distinction between the submarine so-called and its more modern evolution, the submersible—was a vessel of very limited capabilities; in fact, it was essentially in the experimental stage. In those days it was the immediate creation of the inventor, and lacked the finish that studious engineering skill was bound to bring when the commercial possibilities became apparent. Today some of the brightest technical minds are devoting their practical and theoretical skill to the betterment of the art of submarine navigation, and the performances of the best of these later-day boats give substantial evidence of what proper encouragement will accomplish. Nothing during the past year

or two has brought a fuller awakening to an appreciation of submarine vessels than the performances during the present summer of the Italian submersibles of the well-known Laurenti type. Four of these, the *Glauco, Narvalo, Otaria* and *Squalo,* participated in the fleet maneuvers. As one of the circumstances of their participation they were obliged to make the run from Venice, on the Adriatic coast, around to Spezia, on the Mediterranean—a distance of something like 1,250 nautical miles. The boats made the run unaided and entirely upon their own resources, having a cruising radius of action at 8 knots of something like 800 miles, and were obliged to replenish their supply of petrol but once during the entire cruise. These boats are accredited with a surface speed of 14 knots when making their maximum, and they are able to make 7 knots submerged at full speed, and have an under-water endurance of about 40 miles when running at 5 knots. The *Foca,* a vessel of 180 tons surface displacement—20 tons more than that of the *Glauco* type—has just been launched by Laurenti at Spezia, and for that boat a surface speed of 15 knots is promised, and a submerged speed of 9 knots, with a cruising radius of nearly 900 nautical miles at a speed of 8 knots. All of this is significant, because it points conclusively to what can be accomplished by technical skill, and it also shows what remarkably seaworthy craft the Italians have produced upon displacements that have previously resulted in submarines scarcely capable of more than harbor or strictly in-shore service. But to return to the torpedo and its potential usefulness.

Of the relatively large number of torpedoes discharged in action during the war between Russia and Japan, the percentage of effective hits recorded is not a high one. When, however, either the torpedo or the submarine mine did burst in contact with a vessel the results as a rule were highly destructive, if not actually disastrous. The torpedo and the mine thus proved what could be expected of them when they did hit, and if further proof were required the experimental attack against the U. S. S. *Florida* supplied it. While the naval constructors

claim that the United States vessels were built so as to minimize the damaging effects of torpedo attack, still the conclusions are not altogether justified. The experimental attack was so arranged that the attacking torpedo should strike midway between two specially reinforced bulkheads, and tons of coal were carefully distributed so as to reduce the area of injury. In time of action this condition might have been sadly disturbed had the torpedo struck in line with one of these bulkheads. Such a contingency would certainly result in the flooding of at least two compartments, and thus doubling the flooded area, and to that extent, at least, disturbing the stability of the craft and her value as a gun platform.

The modern 18-inch torpedo—thanks to the superheater, the use of the turbine, and the latest development of the gyroscope—is able to run with wonderful precision for ranges up to fully 4,000 yards, making at the latter range as much as 28 knots, while for 1,000 yards the torpedo can go at the remarkable speed of 43 knots. The primary advantage of the long range is naturally to enable the torpedo boat to strike from a distance and thus increase her own probability of getting away. Except during daylight, the chances of a surface boat making a successful target at 4,000 yards is practically out of the question, and during daytime torpedo boats and destroyers would be blown out of the water by the gunners of the rapid-fire batteries. As a result, the speedy destroyer can, at best, only hope to use her torpedoes effectively at night, and the problem then is not an easy one, and the value of her speed in approaching her target is decidedly speculative, because of the tell-tale character of her bow wave. It is true that the searchlight cannot be depended upon to pick up low-lying torpedo vessels at a range of much over 1,500 yards when these boats are approaching stealthily. On the other hand, should the target ship be under way, the layer of the torpedo-boat's launching tube has, beside the dimness of his target, difficulties due to the task of determining the speed of the enemy and the direction in which she is moving, in order to hope to make a successful hit. A dark night would render the determination

of these two prime factors well-nigh impossible, and torpedoes fired under such conditions would have only a very remote chance of hitting. The modern destroyer is counted upon by naval tacticians as a supplementary unit of the battleship squadron, and apart from her use as a scout and service as a picket when the heavy ships are anchored, she is considered as a possible means of striking a sudden and stunning blow during the heat of an action or as a means of intercepting and torpedoing fleeing ships of the enemy or some of his "lame ducks." Work of this sort, naturally, is to be performed either at night or in the twilight, or during thick or hazy weather in the daytime. In each case the commander of the destroyer *is expected to identify certainly the object of his attack.*

Now let us see how far peace-time maneuvers have substantiated the claims made for surface-torpedo craft. Successful attack during the day was soon proved to be quite impossible except in time of fog or thick weather due to heavy rains. Accordingly, the most serious study has been given to the question of night attacks, the commanders of torpedo vessels reasonably claiming under the circumstances a promising measure of success. Analyzed, however, these achievements do not seem to be so menacing as they might appear at first blush. In most of these instances a "hit" has been claimed or awarded the torpedo boat when she had crept undetected within torpedoing range, and had then blown a whistle, fired a gun or given some other indication of her presence. The number of battleships thus theoretically sunk created a good deal of alarm until the collapsible-headed torpedo was developed, and the practical-minded officer insisted that actual hits with these torpedoes alone should count in determining the value of torpedo-boat attack. The results have given a good deal of comfort to the commanders of heavy ships, while they have put the skippers of torpedo vessels upon their mettle and brought them to a far better realization of what they could be expected to do in time of actual conflict. The difficulties of making a real hit have been typically exemplified by actual practice in the Royal Navy. A squadron of battleships and cruisers was sent to sea

at night, and a division of destroyers—without information as to the squadron's position—was detailed to hunt the heavy ships down and to attack them with "soft-nosed" torpedoes. The skipper of each destroyer was obliged to identify in his own mind the ship he attacked—reporting her by name afterwards, and no torpedo was to be considered successfully fired unless it hit the ship of his supposed choice. The destroyers were able to find the armored ships, and succeeded in creeping up within striking distance, and actually firing their torpedoes before being discovered by the squadron, but it is said that not a single torpedo struck home, and no commander was able to identify the ship of the enemy which he had chosen for a target. The Japanese were keenly alive to the risks run by their own vessels, and the difficulties attending identification at night, and, accordingly, during the later months of their war with Russia, their ships were kept within harbor or upon cruising grounds of prescribed limits after nightfall, lest they be sunk by their own torpedo boats. Thus we see that surface-torpedo craft are practically denied a field of usefulness as torpedo boats, pure and simple, during the day, and at night, except under certain conditions, they are a menace to both friend and foe.

The question is: Is it not better to build "scouts" for scouting duty exclusively, and abandon the virtual combination of "scout" and torpedo boat which we are practically striving for in the latest type of destroyers? And, again, had we not better seek a mobile base for the discharge of the improved torpedo in the development of the submarine?

During the French maneuvers we have the records of a goodly number of actual hits by "soft-nosed" torpedoes fired from the submarines, and during the recent Italian maneuvers the submersible *Glauco*, in broad daylight, succeeded in hitting the battleship *Saint-Bon* twice before she, the *Glauco*, came to the surface and indicated her presence. It would have been quite impossible to have accomplished this with any manner of surface craft. The early difficulty of properly judging distances from a submerged boat was due to the imperfect

character of the observing instrument or periscope then commonly employed. Opticians, however, have now taken the matter in hand, and there are a number of satisfactory periscopes which enable the observer to estimate distances with a great deal of accuracy. This accomplished, the submarine boat is able to work in the daytime with nothing above water but this instrument, and that exposed only at chosen intervals. Of course, a periscope is a fairly sizeable target, small as it is, when once discovered by the pointer of a rapid-fire gun, but the difficulty, even in the daytime, with a broken surface on the water, of picking out such an object at 1,000 yards is great indeed. At greater ranges the chance of detection is still more remote, while the capability of the submarine's commander getting a good sight on his target is by no means correspondingly reduced as his range increases. In brief, he is able to take his distance at the full maximum range of his weapon and has substantially all the chances of properly estimating his enemy's speed and bearing that the skipper of the destroyer would have at the same distance, except that the submarine boat lies out of the reach of his foe's gun fire. At night the submarine labors under all of the difficulties peculiar to the surface boat when the submarine is running submerged. Perhaps she is under a greater disadvantage because observation must be entirely by means of her periscope, and with dimness of light this is intensified by reason of optical limitations. But she is able to approach that much closer before there is any possibility of detection, and her chances of hitting are thereby increased.

It must be remembered that the modern submersible is capable of running in her light trim at speeds ranging from 10 to 15 knots, and that in five or six minutes she can be trimmed for submergence and ready to go under water. Her surface speed is her tactical speed, and with it she can cover the distance between her and her target. In her light condition she is less conspicuous than a surface-torpedo boat of corresponding displacement, and once more the likelihood of her getting within striking range is greater. It is therefore plain that any further

improvement in the speed of the torpedo and the speed of the submarine will only add to the effectiveness of their combination, while further speed, and with it necessarily increased displacement and size of target on the part of the destroyer, will only intensify her unfitness for torpedo service.—"The Engineer."

SCIENTIFIC BOILER CONTROL.

At the Institute of Marine Engineers, Stratford, a lecture was given by Mr. G. A. H. Binz on "Scientific Boiler Control." Mr. J. T. Milton (member of Council) presided. After remarking upon the large amount of waste, even with experienced firemen, due to the usual methods of stoking, Mr. Binz advocated as a remedy a continuous and automatic analysis of the products of combustion which would indicate the method of stoking that produced the best results. The carbon in the coal, he said, was not always burned to CO^2; it might be changed only to CO, or any particle of CO^2 might be retransformed into CO if it should, in its passage through the firebed and flues to the chimney, come into contact with atoms of highly-heated carbon. The proportion in which these two gases were present in the furnace gases could only be determined by chemical analysis. A pound of dry carbon burnt entirely to CO^2 gave heat equal to 14,600 B.T.U., whereas the same weight of the same carbon burned to CO only yielded 4,450 B.T.U. It, therefore, followed that if there was a low percentage of CO^2 in the exit gases a lot of the heat was lost, and, inversely, a high percentage of CO^2 denoted good combustion. This percentage could be ascertained by means of a CO^2 recorder, an instrument which produced, practically automatically, a certain number of records per hour of at least one of the products of combustion. There were two factors to be considered in estimating the CO^2 contents of the exit gases—the presence of CO when the percentage of CO^2 was high, and the temperature of the gases at the stack. As CO was a heat

absorber, it was obvious that it would be of little use to produce a set of conditions which, whilst securing a high percentage of CO^2, also had a tendency to encourage the presence of CO in appreciable quantities, but the admission of air was all that was necessary to prevent this initial formation. The possibility of the transformation of CO^2 back to CO was very remote as long as the percentage of CO^2, as shown by the recording instrument, was not more than 14 to 15 per cent., and the formation of CO under those conditions was most probably due to a low velocity of the gases in the furnace at a high temperature, which encouraged contact of particles of CO^2 with highly-heated carbon. A high temperature at the stack was due either to conditions unfavorable to complete combustion of the fuel and the gases given off by it immediately over the grate, or too high a draft pressure. The results in the former case would be shown on the recorder, but in the latter case it was advisable to take into consideration the temperature of the exit gases in addition to the percentage of CO^2. If an engineer could, by the use of a CO^2 recorder, increase the percentage of CO^2 in the exit gases from 5 to 14 per cent., it would effect a saving in coal of 21½ per cent., and if, in addition, he succeeded in reducing the temperature at the stack by 100 degrees, the saving would amount to 24 per cent. A "Sarco" CO^2 recorder was afterwards exhibited, and the lecturer explained its working and construction. In reply to questions, the lecturer said the machine was mainly used on land installations, but instruments had recently been perfected with special fittings for marine work. Where there was a series of boilers the pipes conveying the gases for analyses were connected up from the different boilers so that an average could be taken for the series. In a multi-tubular boiler the gases were taken either from the combustion chamber or the front of the boiler as preferred. The recorded results from the combustion of oil fuel were not so good as those from coal. The opinion was given that, as the samples were taken out at intervals, a record might be obtained which would not be representative, as the samples might be taken on successive

occasions when the doors were opened for firing, but the lecturer stated that this effect would not be experienced when an average was taken. It was also held that, although the recorder showed a worse record of consumption for oil fuel than for coal, it did not necessarily prove the latter to be more economical, as there were differences in the processes of combustion between the two fuels, which might not be shown on the recorder. It was proposed that the lecturer be asked to give a demonstration with the "Sarco" recorder in the experimental room of the Institute.—"The Steamship."

NAVAL ORDNANCE OF THE UNITED STATES.

Rear Admiral N. E. Mason, Chief of the Bureau of Ordnance, in his latest annual report, gives some interesting details regarding the administration of that important Bureau during the last fiscal year, and another branch of the United States Navy Department is adding emphasis to the increasing demand for more auxiliary ships for the battle squadrons. As one would naturally surmise, Admiral Mason's plea is for ammunition ships, and in this he is repeating recommendations which he has previously made upon two occasions. The Admiral presents a convincing argument in favor of the building of such vessels, and in his own words he tells us:

"Two ammunition ships should be constructed for use with the Atlantic and Pacific fleets. The necessity for them has been amply demonstrated during the year in connection with the extended cruise made by our fleets. In the line of supplies there are just two main essentials which must be furnished the fleet to enable it to carry out war operations—coal and ammunition—since the ships cannot carry enough of either to maintain extensive operations. The necessity for coal carriers has been recognized and suitable ships built. Ammunition carriers will be found just as essential, and the Bureau holds it to be even more important that capable vessels be built for this purpose. If the enemy captures or destroys a collier we lose the

collier and, say, 5,000 tons of coal, costing $15,000, or $20,000, but we have an unlimited supply of it within our borders. To refill eight battleships with ammunition also involves about one 5,000-ton cargo. If we lose that we lose millions of dollars' worth of material which cannot be replaced in months, or even years, and without which those ships are helpless."

Some substantial improvements have been made in the big guns for the battleships building, and still greater offensive power is promised for the weapons designed for the battleships last authorized. The big guns of the American Navy have been subjected to some off-hand criticism, and the general public has been led to believe that the United States was not keeping pace with the state of the art abroad. This has been denied by Admiral Mason, and in his report he says:

"Work has been begun on the 12-inch guns for the battleships *Florida* and *Utah*. The 12-inch guns for these ships are of a new mark, 45 calibers long, with a new design of powder chamber, and increased strength along the chase and at the muzzle. It has been stated in the press and elsewhere that our latest types of 12-inch guns are inferior in power to those in use in certain foreign navies. As a matter of fact, the 12-inch guns mounted on the eight latest of our battleships already in commission are equal or superior in power to any 12-inch gun yet afloat anywhere in the world, and the 12-inch guns of our battleships in course of construction will be equal or superior in power to any 12-inch foreign gun of which we have authentic information."

The 12-inch gun, however, is not the finality of the efforts to produce still more effective weapons for the Navy. And Admiral Mason has this to say upon the matter:

"Anticipating possible need of a more powerful gun, the Bureau early in the year completed the design of a 14-inch gun designed to fire a 1,400-pound projectile. The facilities of the Washington Navy Yard are not at present adequate to assemble a gun of this length, but an appropriation for raising the roof of the gun shop over the shrinking pit has been asked of Congress, and if it is made, and made immediately available,

the Naval Gun Factory will be able to undertake the manufacture of such guns early in the coming year."

For some years after their installation on shipboard the 3-inch semi-automatic gun and mounting were far from satisfactory, but the Chief of the Bureau of Ordnance announces that the original obstacles have been overcome, and a very satisfactory weapon of this caliber has been produced. The gun must, indeed, be a superior weapon, because it is being manufactured to replace the three pounders and six pounders heretofore fitted on board battleships and armored cruisers. An improved type of 5-inch gun and mounting has been procured and thoroughly tested at the naval proving grounds with satisfactory results. This gun uses a cartridge case, fires a 50-pound projectile and has a service-muzzle velocity of 3,150 foot-seconds. This is the weapon that will be mounted upon the battleships for anti-torpedo defense.

The projectile question in the United States Navy has reached a critical stage, especially for armor-piercing shell of the larger calibers. The Bureau of Ordnance has felt bound to maintain its requirements upon a par with the reported results obtained abroad, and this has decidedly embarrassed a number of the manufacturers. According to the terms of the annual appropriation for ammunition, the Bureau of Ordnance has been obliged to award contracts for projectiles to the lowest bidders, and this has not produced an encouraging state of the art so far as developing the facilities of many of the firms capable of producing projectiles. A condition something akin to a monopoly has developed which has thrown the vast bulk of this work into the hands of one concern, and no substantial encouragement could, by reason of the wording of the appropriations, be given to other firms to take up this phase of the steel industry. Naturally, no inexperienced manufacturer was willing to submit a bid unless he put his figures high enough to cover the cost of experimenting and to safeguard him against the risks of an untried field. As a result, the lowest bidder was the firm that held the monopoly, and the advance of the art was substantially restricted to the measure of prog-

ress which that firm saw fit to make. Hence many concerns that have not had sufficient experience in this particular work have failed to meet the Government's requirements, and thousands of projectiles have been accepted at reduced prices rather than force the full penalty of non-fulfillment upon these honest endeavors to meet a national need. Because of this condition Admiral Mason has again asked Congress to permit him to make contracts for small lots of shell, irrespective of the question of the lowest bidder, and he hopes in this way to encourage development generally and to increase the Government's possible resources.

In connection with this matter, the report of Admiral Mason has this to say upon armor-piercing projectiles which will in the future comprise the entire battle supply for the main batteries of capital ships:

"Of these, the reserve supply is much too small, particularly in view of the capacity of the plants which are successful in the very difficult work of manufacturing them. Only two firms hold contracts for large armor piercers; and, as yet, but one of them has delivered satisfactory projectiles. There are other firms suitably equipped for this work, but it is, however, a very difficult art, in which success is obtained only after extensive preliminary work in developing processes and training personnel. This preliminary work is expensive, and the firms referred to seem not inclined to undertake it unless they are awarded contracts for projectiles at rather high prices. The appropriation laws are such that contracts for projectiles can only be awarded after public competition. It would seem advisable to authorize placing small contracts without advertisement whenever satisfactory proposals can be obtained, in order that the industry may be advanced. It is earnestly recommended that the appropriation laws also be such that projectiles can be obtained in the foreign markets whenever our domestic factories are unable to supply the Bureau's needs at reasonable prices.

"During the past year the Bureau has, with the aid of private firms, developed a new design for armor piercers which gives

vastly improved accuracy and longer ranges without the loss of any of the qualities of the preceding design. This development constitutes such an improvement as to make it the longest step in advance that has occurred in ordnance material for several years."

This particular achievement is not of a revolutionary character, but the natural result of paying a little more attention to the form of the head of the shell. It is an adaptation of the principle of the Spitzer bullet to big projectiles, so that the more pointed head may encounter less resistance in flight, producing in consequence a flatter trajectory and greater striking energy at long ranges. This same improvement in form, however, has brought in its wake added problems, and the principal of these is the attainment of a projectile that is capable of making effective use of its greater striking energy when confronted with the hardened armor that it is expected to penetrate undeformed. This difficulty has not been solved by any of the manufacturers so far as armor-piercing projectiles of the "improved form" are concerned. And the tone is gloomy among these concerns, especially when it is recognized that vanadium is going to add more of an impediment to successful attack.

The powder trust has been subjected to unpleasant notoriety so far as the "infant industry" is concerned, and the Government investigation is still in progress. In connection with this matter of powder supply the Chief of the Bureau of Ordnance says:

"During the past two years the Bureau, as far as annual appropriations would permit, has been accumulating a reserve supply of powder. This supply is not nearly as large as is deemed necessary, but the situation is vastly improved over that of two or three years ago. In addition to a reserve supply of powder actually finished and ready for use, it is held that the national necessities call for the maintenance of powder factories with capacities as great as possible. There are, in addition to the naval factory at Indian Head, four factories owned by private firms, and the recently completed army fac-

tory near Dover, N. J. The maximum capacity of these plants is considerably in excess of the requirements for filling our prospective needs, except in the event of hostilities. One of the private plants is now entirely shut down, and the other three are running at a greatly reduced output. It is recommended that the plant at Indian Head be extended, but that it be run at less than its full capacity, so that enough work will be left for the private plants—to encourage their owners to maintain them in condition, and to retain their valuable forces of chemists and workmen.

"The joint Army and Navy Powder Board has continued its work in connection with the specifications, methods of inspection, etc., and the two services purchase and manufacture their powder under exactly the same conditions with regard to methods, processes, etc., with consequent simplification and economy. One duty of the Powder Board is to recommend the price to be paid for powder, basing their calculations upon data obtained in the operation of the Government plants, and a small reduction was made during the last fiscal year in view of the slightly lower price of raw materials. The capacities of the Government plants are probably now such that, during the continuance of peace, the Government may be considered nearly independent of the Du Pont powder companies, and there is no danger of its having to purchase powder at exorbitant prices. Indeed, the companies have always accepted the price named by the Government, and it is only fair to state that, during the past few years, when the Bureau was obliged to purchase large quantities of powder, these companies have never taken advantage of the situation to charge exorbitant prices. The national welfare requires the encouragement of these companies to keep up their plants and their trained forces, even if the output of the Government plants has to be kept much below their maximum capacity."

It may be remarked in passing that but for the naval powder factory at Indian Head, the Government would never have been in a position to confront the private manufacturers with the actual figures of cost of production, and thus brought about

the very great reduction in price that has followed; and, further, the dictum of the Army and Navy Powder Board has been uniformly met with a protest by these private producers every time a reduction in price was recommended. The investigation by the United States authorities of the so-called powder trust will probably give even a better idea of the situation than the conclusions drawn by Admiral Mason.

In connection with the military character of the smokeless powder used in the United States Navy, we are informed that the quality, composition and characteristics of the powder have not been changed during the year. And, further, the report informs us:

"As for its ballistic qualities, the Bureau is now sure that there is no known superior. Smokeless powders can really be divided into two general classes—those which contain nitro-glycerin and those which do not. The former have certain advantages, which are more than nullified by the rapid erosion or wear of the guns which is entailed by their use. Whatever may be the disadvantages of our powder, which contains no nitro-glycerin, as regards cost, lack of keeping qualities, tendency to 'flarebacks,' etc., we will be able to do better shooting with it in battle than with any other kind. Those services which were formerly committed to the use of nitro-glycerin powders now show a tendency to abandon them, and no service using the other variety seriously thinks of making any radical change.

"There is, undoubtedly, an inherent tendency for pure nitro-cellulose powder to decompose when stored at the high temperatures frequently found in ships' magazines. This has resulted, in foreign navies, in catastrophes; but similar ones have occurred in ships with nitro-glycerin powder. While we have no instance of even a minor explosion, the Bureau has been put to great expense by having to replace powder which showed doubtful, if not low, stability. Although a successful process has been developed for repurifying this material at a little less than one-fourth of its first cost, the expense due to deterioration of powder is, in view of the enormous amount

now carried by ships which are often in tropical waters, likely to be high. A system of magazine refrigeration to keep temperatures uniform at from 65 degrees to 70 degrees Fahrenheit would result in trebling the life of powder on board ship. Moreover, magazine cooling will virtually remove the danger of explosions from spontaneous combustion, which danger, in the light of the *Jena* and other disasters, must be recognized will tend to improve the accuracy of firing through the more uniform ballistics obtainable, and its cost will be partly, if not wholly, offset by the lesser expense of reworking. The general adoption of magazine refrigeration is therefore recommended.

"Investigations have resulted in minor improvements in methods and processes, and have improved the quality of the powder. Though no radical change or improvement is in sight, it is now likely that a way of very considerably improving the stability and keeping qualities of the powder will be developed in the near future. This will only be an improvement, however, and in the present state of the art there is no material or method which will make nitro-cellulose, or any other smokeless powder, so resistive that it will withstand storage conditions on shipboard for indefinite periods.

"During the year the Bureau has established a laboratory in the Philippine Islands for testing and watching the powder on that station. Though temporarily located and not yet in good running order, this laboratory has been of great value, by obviating the delays in obtaining reports on samples shipped home, which delays were obviously dangerous in view of the high-storage temperatures on the station."

In connection with the production of smokeless powder at the naval factory at Indian Head, the following facts may be of interest: During the first ten months of the fiscal year 912,923 pounds of new powder were made, besides which 107,381 pounds of powder were reworked into good powder in a little over four months. The factory has been running at a rate of output of about 1,500,000 pounds of powder per annum for a large part of this year, and will actually manufacture a total of 1,300,000 pounds, an advance over any

previous year of 30 per cent. During the ten months referred to $25,379 was saved by manufacturing mixed acid from the raw material. As a source of profit, therefore, the acid plant has succeeded beyond expectations, and has, incidentally, avoided the inconvenience of delayed deliveries of acid. The solvent-recovery plant has amply justified its establishment, having saved, during ten months, $23,397.61 in alcohol recovered. For the full term of the past year the solvent-recovery plant netted a saving of $40,943.35. These figures are significant of what can be accomplished by a proper co-ordination.

During the past year extended experiments were made by the Bureau of Ordnance with guns of various calibers to discover the proper number and the arangement of air ducts for the gas-ejector attachments. Conclusive and satisfactory results were obtained, and all of the guns now being manufactured are fitted with the most efficient arrangement. The idea of using a closed turret and keeping the turret chamber under a moderate air pressure has been definitely approved by the Bureau as an auxiliary to the regular gas-ejector attachments. This arrangement has proved not only a valuable aid in expelling gases from the bores of the guns, but it has also been found to be the most convenient method of ventilating the turrets in action. As a result of the Special Turret Board's investigations and report, a number of radical changes have been ordered. These are material efforts not only to localize the danger areas within the turrets, but to minimize risks as far as possible by eliminating the personal factor to a large extent through the medium of automatic devices of a reliable and simple character. Speaking of the battleships now building, the report of the Bureau of Ordnance informs us that:

"The ammunition hoists for all these vessels will be of the two-stage type, but differing in details for each class. In order to ensure a supply of ammunition adequate to the possible rapidity of fire of the guns, two-stage hoists were considered necessary, and it is believed that those which are to be installed in each class will prove fully equal to the requirements of both rapidity and safety.

"One of the ammunition hoists of the *Delaware* class, which are of a design submitted by the Bethlehem Steel Company, and which are being manufactured by that company under contract, was recently tested at the Naval Gun Factory in connection with a competitive test of electrical equipments for these hoists. Three different types of hoist control and of hoist motors were tested, and the tests satisfactorily demonstrated the ability of the electrical manufacturers to comply with the additional requirements of the latest type of turret mount and ammunition-hoist installations.

"Hand hoists will be installed in the turrets of all three classes and in all future turret installations. Those of the *Florida* and *Delaware* classes will be entirely independent of the main hoists. For all classes, the complete separation of the gun chambers from the handling room is satisfactorily ensured at all times.

"To make the safety of the earlier-type turret installations as little dependent as possible upon the careful observance by their crews of certain rules and regulations, the stowage therein of the necessary electrical apparatus has been aranged so as to render the latter practically if not absolutely innocuous. Center-line bulkheads have also been fitted in double-gun turrets in order to increase the safety of loading operations of either gun. These changes have been effected in the turrets of all vessels now in commission, and where possible will be made features of the turret installations of vessels which are now refitting. To ensure the separation of the handling rooms from the turret chambers, automatic shutters are the only devices so far fitted. A trial installation of the trunked-in single-stage hoist has been placed in the 12-inch turrets of the *Idaho,* and one will be placed in the 13-inch turrets of the *Oregon*. It is expected that a thorough test of the type will be obtained at the first record-target practice of the *Idaho*. If this system proves efficient it should be made a feature of the heavier turret installations of all the older vessels in which it is impossible, without very great structural changes, to fit two-stage hoist equipments.

"The power hoist and rammer equipments of the 8-inch turrets of the *Vermont* and *Louisiana* were replaced by hand-worked equipments before the departure of those vessels for the Pacific. Reports of the efficiency of the new installation have been so satisfactory that a similar change has been made in the 8-inch turrets of all vessels in commission excepting the *Kearsarge* and *Kentucky*, where it is practically impossible. The advantages of this type of hand installation in 8-inch turrets are the complete separation of turret chambers from handling rooms at all times, much less liability to breakdowns and increased rapidity of fire.

"A considerable increase in the rapidity of fire beyond what was considered possible at the time they were installed is now prevented only by the ammunition-hoist motors of a great many of the older vessels not being of sufficient capacity, and it is highly desirable that new motors of greater power be provided. In all of these vessels it is practically impossible to install two-stage hoists for increasing the rapidity of ammunition supply, which makes it necessary to have greater motor power to increase the speed of the present-type single-stage hoist, so that the maximum rapidity of fire of which the installations are capable may be attained. In certain vessels it would be necessary to increase the capacity of the electric plants in order to provide for this increase in the power of the hoist motor. If this is done, the voltage of all the plants should at the same time be brought up to the latest standard, which would result in considerable economy and increased efficiency.

"An ammunition-hoist motor automatic controller supplied for one of the 12-inch guns of the *Missouri* has given such satisfaction in service as to warrant a recommendation that controllers of this type be fitted to all turret-hoist motors. With automatic control of the motors greater average speed of hoist may reasonably be expected, as well as much less liability of damage to apparatus by careless or inexpert operation. Apparatus of this character is not unduly complicated, and with it the hoistmen may be trained to the necessary degree of expertness in a comparatively short time.

"The mechanical-control gear for the elevating motors of turret guns, which were installed about a year ago in two of the vessels of the fleet, has given very satisfactory results in service. It gives control through a wide range of rolling speeds, making it much easier to keep on the target than has been the case heretofore. The Bureau considers this device of such great military value that it should be fitted to all turret guns.

"The latest-type sight and telescope is of such design that the turret hoods and sight holes are very much smaller than those formerly fitted. Also, with the present-type of sight and pointer's hood it is practically certain that the gun pointer would be seriously injured, if not killed, were the hood to be struck by a heavy projectile on its front surface, while with the latest-type sight in the same case he would, in all probability, receive no serious injury."

As was to be expected, the Chief of the Bureau of Ordnance has something to say upon the all-important question of fire control. He informs us:

"During the year eighteen battleships, including all of the Atlantic Fleet, have been equipped with fire-control systems and instruments. Three different types of instruments for the electric transmission of ranges and deflections for visual display to sight setters at each individual gun have been installed. Further purchase of such instruments is temporarily deferred pending results of service proof of these three types. The necessity of having an efficient fire-control system, to be able to reap the reward of efficient ordnance material and skillful gun pointers and crew, was briefly pointed out in the last annual report."

In connection with this matter, it is not without interest to recall the fact that it was publicly announced with persistent official emphasis that the Atlantic Fleet was bound for the Pacific upon a peaceful practice cruise, and that the circumnavigation of South America was merely to be a long-distance test of the machinery endurance of the ships. As every one knows, the destination at that time was another home port, namely, San Francisco. Yet, notwithstanding these facts,

which logically should have been the common knowledge of the Fleet Commander, Rear Admiral R. D. Evans, that officer positively refused to put to sea until his ships had been properly provided with complete installations of satisfactory fire-control systems!

The report also informs us that the specifications for new armor require that it shall meet very severe tests, and it is announced that:

"In conjunction with the armor manufacturers, the Bureau is now engaged in a series of tests of experimental plates, looking to the production of an armor of increased ballistic resistance. These experiments give promise of a successful result."—"The Engineer."

THE "LATOUCHE-TREVILLE" GUN EXPLOSION.

The excellence of the French naval ordnance was until quite recently, and very rightly so, taken as granted the world over, one of its characteristic features, and one which excited general admiration, having been absolute safety in action. Then, without premonition, and for no very apparent cause, French naval guns have had public attention attracted to them in a most unsatisfactory way. The probable reasons which have led to recent accidents with naval guns on board French ships afford matter for the consideration of all who are interested in naval problems; in many quarters, however, the subject is not approached with an unbiased mind, and there are many specialists, even in France, who find an easy way out of difficult and involved explanations by attributing to the "bad quality of the *matériel*" all incidents which occur. Such a statement cannot be taken as throwing any light upon the question, and it is most unreasonable to believe that a gun, or any machine, designed and built for doing a specified work, which work it has carried out well for months and years, should fail through "bad quality" while being used for doing that same class of work. In the particular case we are reviewing the explanation

for the explosion is to be found outside the gun itself; the latter remains unimpeachable.

The 7.6-inch gun in the *Latouche-Tréville,* to which the accident has been traced, is of the 1887 pattern. The following French ships are armed with guns of that same type: *Jemmapes* and *Valmy,* 13-inch caliber; *Brennus,* 13-inch and 6.4-inch calibers; *Carnot, Charles Martel* and *Jauréguiberry,* 12-inch and 11-inch calibers; *Bouvines* and *Tréhouart,* 12-inch caliber; *Depuy de Lôme,* 7.6-inch and 6.4-inch calibers; *Charner, Chanzy, Bruix* and *Latouche-Tréville,* 7.6-inch and 5.5-inch calibers.

On no occasion since they were put in the service—now about fifteen years ago—had any of the large number of guns in question, arming battleships and cruisers, given rise to any incident, so far as we are aware; and these guns were the first 42 and 45-caliber guns built for firing with smokeless powder. Had there been any serious defect in their construction it certainly would not have taken so many years to become apparent. The fact must not be lost sight of in this connection that the French naval guns are, and have always been, fired regularly. It cannot but be recognized that there is another factor; there are, in fact, two terms to the problem—the gun and the men behind the gun. Data recently published in the French periodical "Le Yacht" make it possible to gauge the situation.

As evidenced by the article in "Le Yacht," and by the particulars given in the "Manuel du Marin Canonnier," the firing mechanism of the *Latouche-Tréville* gun—illustrated in Figs. 1 to 3 herewith—consists of a spring striker fitted to a bolt, which is movable in a slide, cut radially in the breech face. The bolt is fitted with a percussion point, and is made with a nose, Fig. 3, which lodges in an eccentric groove cut in the gun and ending in a recess, with which it is connected by a curve. When the breech is opened by causing the breech block to revolve, the nose of the bolt rises first round the connecting curve, and by being guided in the groove draws the shank of the bolt outwards, by which means the striker is no longer opposite the primer. Inversely, when the breech block is closed

the nose of the bolt is, at the stop cleat, led inside the groove, and the striking piece is only brought in front of the primer when the bolt is in a line with the recess, or, in other words, when the gun is ready for firing. The regulations further prescribe that the primer must only be inserted after the closing

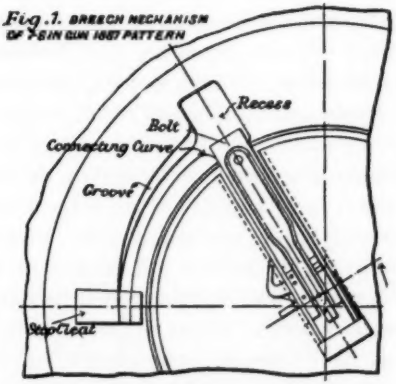


Fig. 1. BREECH MECHANISM OF 9·2 IN GUN 1887 PATTERN

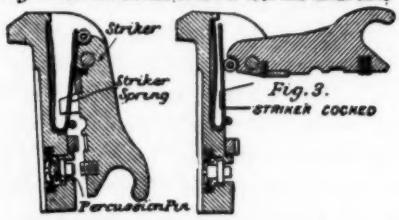


Fig. 2. PERCUSSION MECHANISM OF 1881 AND LATER GUNS

Fig. 3. STRIKER COCKED

Fig. 4. BOLT

of the breech, and that the latter should be opened only after removing the primer and uncocking the striker.

Such are very briefly the particulars concerning the firing mechanism in question, which dates from a period at which nobody ever thought of carrying out rapid firing with a

7.6-inch gun. There is nothing astonishing in the fact that this mechanism should have been in the service for so long a time without giving rise to any complaint; it was only necessary to use it on the lines according to which it was designed and manufactured, taking care that all the maneuvers were carried out accurately, rapidity in their execution being, so to speak, a secondary consideration. The bolt, which is the characteristic piece in the mechanism, dates even as far back as 1870; its use has therefore been endorsed by a long and satisfactory experience.

Now on board the *Latouche-Tréville,* and according to all the reports which have appeared, it was sought, with a gun of a pattern over twenty years old, to fire as rapidly as is possible with a gun of a modern type. The service regulations for this older type of gun, says "Le Yacht," were not followed, the breech block having been opened out without removing the primer, without uncocking the striker, and leaving the lanyard for releasing the striker hooked in place, which lanyard was connected at the other end to the gun mounting. When, therefore, the breech block was turned back after being unscrewed in its seating, the tension set up on the lanyard caused the bolt to travel towards the center of the breech block, the striker resumed its position opposite the primer, and, the tension on the lanyard increasing, the charge was fired. A very great breach of regulations was thus committed in the handling of the gun, and the sequence of actions was ascertained when the breech block was recovered and seen to contain the fired primer in its seating.

It is necessary here to explain that the *Latouche-Tréville* was at the time performing maneuvers under steam, describing a square, and carrying out firing practice against a floating target in the center of the square. When the ship neared the angles of the square she turned, and the target was for a time out of the line of sight. Firing was then suspended during four or five minutes, and this suspension was taken advantage of to change the gun crews. Such was the occurrence before reaching one angle, the gun had been loaded, but could not fire

at the target, and the gun crew was changed. Then it was noticed that the regulations had not been complied with, which prescribe that when a gun in such a circumstance remains loaded, the breach block should be opened out after removing the primer and placing the striker at safety. Some confusion must have arisen at this point, and the breech block was opened out without removing the primer, and evidently without changing the position of the striker. Three minutes only had elapsed between the loading of the gun and the accident; there was therefore no back-flash, for the gases would have had time to cool had there been any, nor any action attributable to smouldering débris, for on opening the breech of a loaded gun there is no draft established through the bore, the projectile closing this up completely.

The author of the article in "Le Yacht" questions whether it can be asserted that the mechanism, which we have briefly described above, is a perfect mechanism. This appears to us to be quite beside the real question. There are, it is true, very few pieces of mechanism which are perfect, but in every case there is one correct way and several wrong ways of using any mechanism. The point at issue is to show for what particular object the mechanism described was designed, and how it was used. If designed with a view to rapid firing, it was certainly a bad device. If, on the other hand, it was designed for slow firing—and this cannot be gainsaid, owing to the ancientness of its type and to the fact that its use for slow firing formed the subject of a special regulation—then it is free from all reproach, as is proved by the long period of years during which it has given complete satisfaction under normal service conditions.

The practical conclusions which may be drawn from the above remarks are various. In the first place, it is idle—and dangerous, as has been proved by the accident to which we refer—to endeavor to serve a gun of an old pattern in a similar way to a new type of gun. Further, it is most unreasonable to compare, as is constantly done in France, the results obtained with an old type of ordnance with those obtained elsewhere

with a modern type. Finally, before delivering to the personnel in charge, as does "Le Yacht," a certificate of superiority, it would be quite reasonable to acknowledge that this personnel, like that of any other navy, may occasionally make mistakes which are often traceable simply to a lack of technical enlightenment on particular subjects. One circumstance in the accident in question has hitherto remained unexplained: All French naval officers who have some acquaintance with the working of turrets are greatly puzzled as to how thirteen men could have found room in the 7.6-inch gun turret of the *Latouche-Tréville,* in which the seven gunners prescribed in the regulations for serving the gun have none too much space, and they conclude that the relief of the maneuvering party was not carried out with all desirable order and discipline.

Experts in the subject of explosives, on the other hand, cannot understand how a charge of powder as low as the drill charge used on that particular occasion, 6.6 kilograms (10.54 pounds) of smokeless powder, according to the hand-book above referred to, can have blown away the turret cover, seeing that the explosion did not take place in a closed-in space, for, besides the normal outlets, such as the gun embrasure and the sighting port, the turret door had been left open. These experts are therefore quite justified in believing that, with a view to accelerate firing, a certain number of extra charges had, most imprudently, been collected in the turret, and placed there unprotected, ready to be used. The simultaneous inflammation of these extra charges can then readily be taken for granted, leading to the blowing away of the turret cover. It is difficult to account otherwise for the magnitude of the explosion.—"Engineering."

BREECH BLOCKS.

The accidents which have recently happened in the French Navy, and to which we have referred in former issues (see "Engineering," vol. lxxxvi, pages 44 and 579), have not only given rise to criticisms of a purely theoretical and technical

nature, but also to polemics of quite a different character. Among the latter may be mentioned French polemics, which are mostly political, and are conducted by Members of Parliament or journalists of the Opposition, whose bias it is to discover, or to assert, that everything French is in a very bad way, indeed. They stop short, however, at all demonstration, and are not able to put forward any exact arguments in defense of their statements. Other polemics which are raised may be said to be of German origin, and these are mostly of a commercial order. German writers seize every opportunity for putting before the world at large the real, or the supposed, imperfections of goods which are not of German manufacture; they generalize without the least hesitation and compunction, even when such goods are adopted and found eminently satisfactory by many nations outside Germany. This explains, for example, the constant recurrence in the German military journals of articles dealing with a very old subject, to wit: the very great safety, and the innumerable qualities, of the German wedge breech-block system, advantages which, it is said, are not possessed by the screw breech-block system adopted in this country, in France, in the United States and elsewhere.

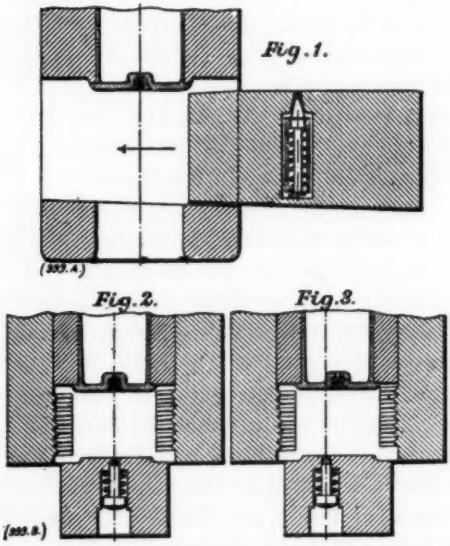
All the criticisms to which we refer, and which are written in a minor key, start from a false standpoint. We called attention to this in a former article. They deal with a highly-improved type of modern wedge breech block compared with a screw breech block of an ancient pattern. The comparisons thus put forward appear striking to some persons who take them up without further consideration, and their statements, made on the strength of such comparisons, are then used to strengthen the case of the wedge. An instance of this was recently afforded by the retired Admiral Bienaimé, of the French Navy, now a member of the Opposition in Parliament, who, commenting upon the *Latouche-Tréville* accident at a sitting in the French Chamber, asked why the wedge breech block was not adopted in the French Navy. His remarks have been given great publicity in all military reviews, especially in those published in German.

Seeing that the breech-block question "is always with us," we thought it would interest our readers to have a few data relating to this question set down in a straightforward way. We base these upon the testimony of a French expert, Major Ferrus, of the French Artillery, to whose articles in the "Revue d'Artillerie" we have already referred (see "Engineering," vol. lxxxv, pages 6 and 207).

If we take first the ancient pattern of wedge breech block, we find that, owing to its transverse motion, it could not work with a plastic gas check; a metallic gas check, a kind of Broadwell ring, had to be used. But, by reason of its transverse motion, the wedge breech block did not act symmetrically on the ring, and after a certain number of rounds the ring became ineffective as a gas check. With much care and precaution this disadvantage could be allowed to continue; it could never be set aside completely in the older practice.

The disadvantage in question has disappeared from the modern type of wedge breech block, owing to the general use of the metallic-cartridge case for all caliber guns, from the field gun to naval guns of 11 inches and 12 inches. That the metallic-cartridge case be specially advantageous or otherwise for the latter—naval—guns is a question upon which many artillerists are divided. This point, however, need not be considered here, neither is it necessary to enter into detail upon the mechanical parts for working both types of breech blocks. The fact nevertheless remains that the modern wedge breech block has found at last a gas-checking device which gives satisfaction, owing to which the safe working of the breech block is, we may say, effected naturally, for, by reason of the transversal motion, the striker can only arrive opposite the primer when the breech is completely closed, as will be seen clearly from the diagram, Fig. 1, herewith. The wedge breech block is comparatively simple to manufacture. This fact is, however, of small moment to the military man who has to use it. But what is of greater importance to him is the other fact that it has several disadvantages. It requires that the cartridge be placed by hand quite close to its final posi-

tion for firing, otherwise it is sure to be cut or damaged by the block during its transverse motion, while the wedge weighs about double the screw breech block for an equal caliber; a wedge breech block for a 12-inch gun weighs approximately 30 cwt. Although the working of the wedge be apparently light and easy, it becomes fatiguing when rapid firing takes place. We know of experiments carried out with field guns fitted with the most improved type of wedge breech block, during which the gunner was absolutely exhausted after a few



minutes' firing. In short, the modern type of wedge breech block may have advantages, but it certainly has its disadvantages also.

If now we take the older pattern of screw breech block, we find that this was not characterized by any single type of gas-checking device, for it gave quite as good results, from the point of view of obturation, either with the metallic or with the plastic gas checks, or with the cartridge case. This older pattern was designed and manufactured without any reference

to rapidity of firing, and with a view to the use of quick-burning powders. It has of late come into prominence owing to the fact that it has been used, such as it was, with quick-firing guns, or with guns firing slow-burning powders, and exposed under these conditions to back-flash, the necessary alterations corresponding with the variation in the duty not having been introduced.

This older pattern, whatever may have been the form in which the powder charge was served, is illustrated in the diagram, Fig. 2. The breech block and the bore of the gun are concentric, and the striking piece is in the center of the block. The firing mechanism was so arranged as to prevent its acting upon the striking piece so long as the breech was not completely closed. It is, nevertheless, perfectly evident that should the point of the striking piece, through any cause, project outside the front surface of the breech block, and become fixed in that forward position, it will strike the primer when the breech block is driven home, and the round will be fired before it has been possible to give the rotary action for finally closing the breech. A glance on Fig. 2 is sufficient to show that herein lies the source of grave accidents, and it is astonishing that this possibility of causing premature firing so long escaped all gun manufacturers, whatever be their nationality, and not only at the time when guns fitted with the screw breech block for using both ordinary cartridges and metallic cases were first put in service, but also long after.

No screw breech block of the older pattern was provided with a device for preventing back-flash when firing powder charges in bags; but so long as no quick firing is attempted with guns fitted with this breech block there is no very great harm to be feared from the flare-back, provided no powder charges are deposited near the gun with a view to facilitate quick firing.

From the above it will be seen how easy it is to establish—as is constantly done—a comparison which is advantageous to the modern wedge breech block as against the older pattern of

screw breech block. Conclusions derived from such a comparison have no practical value whatever.

We illustrate in the diagram, Fig. 3, the modern pattern of screw breech block for guns firing with ordinary cartridges or cartridge cases. In this pattern the breech block and the bore of the gun are eccentric in the vertical direction, and the striking piece is not in the center of the breech block. The effect is—as will be seen on reference to Fig. 3—that when the breech block is driven forward for closing the breech the point of the striking piece, even should it project out, can have no action on the primer. As in the case of the wedge, the striking piece arrives opposite the primer only when the breech is completely closed, this being when the rotary action is completed. The modern screw is therefore absolutely as safe as the modern wedge breech block in this respect. The extent of eccentricity of the striking piece in regard to the primer is of no importance; it is quite as easy to make it, say, ¼ inch as 2 inches.

The modern screw breech block for guns firing bag cartridges is connected with an apparatus which, when the round is fired and as soon as the opening-out action of the breech commences, delivers through the bore of the gun a cold-air current maintained sufficiently long and at a sufficiently high pressure to drive out at the muzzle all inflammable gases and all residues which might have remained in the powder chamber. There is therefore no risk whatever in regard to the premature igniting of a fresh charge. The arrangement gives as great a degree of safety in working the gun as is obtained with the wedge breech block and cartridge cases, and it insures further the great advantage, in the case of heavy-caliber naval ordnance in turrets, of doing away with the escape of gases inside the turrets from the empty cartridge cases as these are ejected; such an escape of noxious gases inside turrets, proceeding from 11-inch or 12-inch cases, is far from being a desideratum.

All the improvements embodied in the modern screw breech block form the subject of numerous patents. It is not within the scope of this article to establish a comparison in regard to

such patents; they deal with devices which have found application. The best of these devices achieve the objects for which they were designed, and thus characterize the modern pattern of screw breech block, and this can more than stand a comparison with the modern wedge. It is much lighter than the latter; it is worked at least as rapidly; it facilitates the introduction of the charges, because it does not make it incumbent upon the gunner to push the charge by hand quite close to its final position for firing; and it is perfectly safe in every respect. Its safety is the more marked the larger the caliber of the gun, and this is an important point to be noted, owing to the present development of naval ordnance.—"Engineering."

THE AUTOMOBILE TORPEDO OF TODAY.

By A. M. HOFFMANN.

The general public has but a very imperfect idea of the advance that has been made in the development of the automobile torpedo within the last few years. For a great many years after Whitehead built the first of these instruments of destruction they were notoriously unreliable, despite all of the skill and cunning with which they were fabricated. The principal trouble lay in keeping the torpedo on a straight path. Its powers of inflicting damage when it did hit were undeniable, but there was a large margin of painful doubt before the torpedo finished its run; it was just as apt to hit the ship discharging it as it was likely to hit the target toward which it was started. Only a very few years ago, the same sized torpedo was issued generally to all vessels without regard to the different fields of service for those craft; and the largest of the torpedoes was not more than 3.55 meters (13.98 feet) long. Today, however, the torpedo has grown to a length of fully 5 meters (19.69 feet), and a distinction is made in assigning these weapons to vessels, torpedo boats being fitted with 18-inch torpedoes of very high speed but shorter range, while the heavy-armored ships carry torpedoes

of 21 inches diameter of greater effective range, but lower speed. This is instructive, inasmuch as it shows an outcropping of the eternal tendency to specialize, class distinctions thus developing even between torpedoes; and it has been suggested that before long we shall see a further differentiation in the form of a particular style of torpedo to be carried by submarine boats. In fact, it is believed by some naval experts that the submarine boat will soon prove to be the only practicable craft from which the best of the automobile torpedoes can be fired in order to secure the fullest advantages of the great speed and range now attained by these weapons.

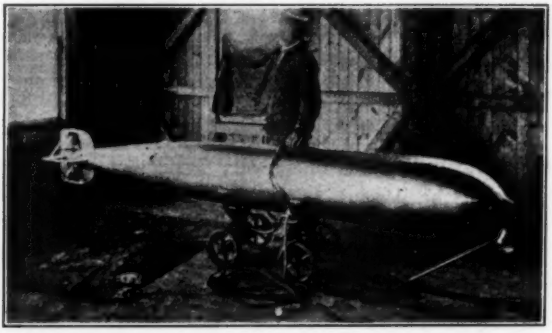


Fig. 1.—THE LATEST TYPE OF 18-INCH TORPEDO.

The motive power of the modern torpedo is compressed air. Ten years ago the air flasks of the largest torpedoes were charged to a pressure of 1,350 pounds to the square inch, while today the working pressure for the latest types is 2,250 pounds to the square inch; and there is reason to believe that we shall have a further increase as metallurgical advances make it possible to fabricate air flasks of moderate weight which shall be capable of safely withstanding the stress of higher pressures. Pent-up energy of this sort makes the air flask, by itself, a weapon of no mean potentiality. Three years ago the French battleship *Jaureguiberry* was struck by a torpedo during peace-time practice, and the air flask ex-

ploded with sufficient force to crack one of the big propeller struts and cause such leakage around the stern—by reason of damaged plating—as to compel the docking of the ship and incidental repairs, which consumed some weeks. This is significant of the power stored up within these weapons for their self-propulsion.

Until within the past year or two the range and speed of the torpedo were limited by the initial capacity of the air flask; and the pressure in the flask began to lessen, of course, from the first moment air was permitted to pass to the driving engines, and it did not seem possible to mend matters in that direction. At this point, however, American ingenuity came to the front and devised a means of increasing the mo-

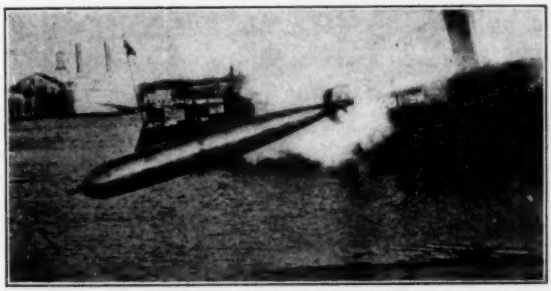


Fig. 2.—Discharge of a Torpedo from the Deck of a Torpedo Boat.

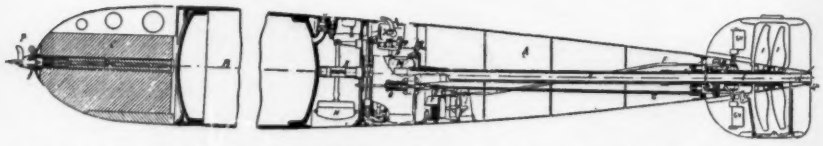
tive capacity of the initial-air supply by causing its expansion through heat skillfully applied. This was a courageous undertaking, because, at first blush, there seemed a dangerous menace in the possibility of overheating the air and bursting the flask. However, mechanical cunning overcame this obstacle by causing the pressure in the air flask to automatically regulate the flame which superheated the compressed air, and in this manner the developing pressures were made to balance and control themselves. As a result of this pioneer work, the first 21-inch torpedoes attained very remarkable results; in fact, the speed was increased nearly 50 per cent.,

while the effective endurance or range at the old speed was more than doubled. Since then, correspondingly good results have been secured with the 18-inch torpedo, and the following table will show directly what the superheater has done:

RANGES OF 18-INCH TORPEDO UNDER BOTH CONDITIONS.*

	Air unheated. Knots.	Air heated. Knots.
At 1,000 yards	35	43
At 1,500 yards	30	40
At 2,000 yards	28¼	38
At 3,000 yards	23 to 24	32
At 4,000 yards	18 to 20	28

It may be of interest to know in a general way how this is accomplished. In addition to the air flask charged with the motive force for the torpedo, there are two or three small flasks which are filled with alcohol and yet retain a little



A, Afterbody. *B*, Air Flask. *C*, Gunpowder Charge. *J*, Air Valve. *M*, Turbine. *N*, Reducing Valve. *V*, Gyroscope. *X*, Superheater.

Fig. 3.—SECTIONAL VIEW OF A TORPEDO.

space for a reserve of air. These flasks or tanks are connected to a burner in the big flask or air chamber. When the torpedo is discharged from the torpedo tube the pressure used to expel the weapon—either air or powder—is sufficient to open a little valve which turns on the air to the engines and at the same time opens a connection between the air chamber and the flasks containing alcohol. After the engines have been running a few moments there is a difference between the pressure in the fuel flasks and the pressure in the motive-air chamber—the latter being lower. As a result,

* The latest development of the 21-inch torpedo is said to have a range of 7,000 yards.

liquid fuel is forced into the burner in the air chamber and at the same time a cunningly-devised trigger is released which explodes a fuse and ignites the alcohol. Immediately, the heat thus generated causes the air in the chamber to expand and incidentally the working pressure is raised. This pressure, after reaching a point above that in the fuel flasks, restrains the flow of the alcohol automatically until the chamber pressure is again lower than that of the air in the fuel system, the pressure of which is reflectively maintained by the surplus power developed in the main air flask. This added gain in motive force by the use of heat would be of little avail if it were not for the "reducing valve," which stands guard between the air chamber and the engines, permitting air at a uniform speed and a reduced pressure only to be fed to the motive mechanism, in this manner preventing the sudden expulsion of the air and the probable destruction of the engines by reason of the wracking vibrations of too high a rate of revolution. This reducing valve is one of the cleverest features of the modern torpedo, and is automatic.

The Whitehead torpedo, which has followed the American, or Bliss-Leavitt torpedo, in the adaptation of a superheater, works in a different way, the superheater being placed outside of the air chamber and between the "reducing valve" and the motor. As a result, the reducing valve likewise controls the pressure produced by combustion and automatically both the air and the fuel supply, so that it is able to maintain a constant temperature irrespective of the quantity of air or fuel used. The secondary advantage of this arrangement lies in the fact that the air exhausted by the engines is warm and the risk of the formation of ice or frost in the moving parts is eliminated. Under the old condition, where the air was not superheated, the expansion at the exhaust valves was so great that it not infrequently reduced the temperature sometimes to several degrees below zero. This not only produced frosting, but it congealed the lubricant and seriously handicapped the working efficiency of the machinery. In addition to this, the cold water of winter in northern

climates helped to this end—it is impossible to run the ordinary cold-air torpedo when the temperature of the water falls to the neighborhood of 40 degrees Fahrenheit, because of the effect upon the initial pressure in the air chamber, and the superheater has thus removed one of the obstacles to effective service in winter time.

Until recently torpedoes were driven by a wonderfully compact little engine of the ordinary cylinder or reciprocating order known as the "Brotherhood" balanced type. Although small enough to be housed within a good-sized cheese box, these engines have been able to develop something over 60 horsepower, but the turbine has now supplanted them and added greatly to the speed and to the range of the torpedo by taking up less room. The gain in range has been due to the fact that the motive air is used more economically, while the increase in speed followed because of the fewer moving parts and the incidental reducing of friction.

Until the last few years the gyroscope installed in torpedoes was spun by a spring which was generally wound a short while before the torpedo was launched. Apart from the shock due to this sudden impulse and the fact that there was thus a limit to the delicacy with which the instrument could be constructed, the gyroscope received no further impulse during the run of the torpedo; as a result there was a gradual lessening of the effective corrective force exerted by the gyroscope or Obry gear, as it was then called. With the introduction of a turbine-driven gyroscope operated by an air impulse not only was the initial shock due to the spring release done away with—permitting a more finely-balanced device—but the gyroscope was kept in continuous motion by a constant air impulse. The increased smoothness of running due to this modified gyroscope has greatly flattened the path of the torpedo, so that it now travels on a straight line instead of the very sinuous one of old. This naturally increases the range and the linear speed of the weapon. The balanced turbine for this work is the invention of an American naval officer, and it is a wonderfully cunning piece of mechanism.

The gyroscope is so arranged that it controls the movement of a little motor which, itself, is of sufficient power to move the rudders guiding the torpedo in a horizontal direction. Before the Obry gear was invented, the torpedo was a very uncertain weapon. Dents or other imperfections in the surface of the torpedo used to cause it to steer badly; and if the vessel were moving at the time the torpedo was discharged, and the torpedo struck the water improperly, it was easily "tumbled" and deflected from its desired target. Especially was this so if the torpedo rolled on entering the water so as to cause its horizontal rudders—which normally control depth—to become, pro tem, vertical or lateral rudders. The Obry gear reduced errors due to these causes to a marked extent, but the improved turbine-driven gyroscope of today has, in its turn, greatly increased these powers of directive correction.

The gyroscope has been still further widened in its usefulness by making it adjustable, so that the original purpose of holding the torpedo to its line of discharge has been amplified in a manner that now makes it possible to expel the torpedo at an angle of quite 120 degrees from its intended target and yet have the gyroscope bring the torpedo gradually round through that arc and then turn it and hold it in a straight line for its objective. The advantages accruing from this permit of the simultaneous discharge of a torpedo boat's full complement of tubes even though they cannot be made to point forward or to bear directly upon the target. All the commander has to do is to adjust the gyroscopes to their proper angles in advance and to point the tubes so that after the torpedoes have described the arcs of these angles they will then point parallel to the fore-and-aft center line of the boat or the direction in which the craft is pointed at the time of their launching. This permits the torpedo boat to approach her target head-on, and thus to offer her most moderate area for the attack of an enemy's gun-fire. When within striking distance all of the tubes can be discharged simultaneously and with excellent chances of hitting the mark and doing effective work.

It was only a very few years ago that $2,500 would cover the cost of a torpedo; today the prices range all the way from $5,000 to $7,100 apiece. The cost of these torpedoes made the Navy Department reluctant to risk many of these weapons in target practice until the coming of the "soft-nosed" or collapsible-headed torpedo. Torpedoes now fitted with these practice heads can be safely fired against a ship without damaging the vessel or risking the loss of the torpedo, and officers and men are now given the training absolutely needful in order to make them of value in time of war.—"International Marine Engineering."

THE SHORT-BASE RANGE FINDER AND ITS PRINCIPLES OF CONSTRUCTION.—NO. IV.

By H. Dennis Taylor.

THE COOKE NAVAL RANGE FINDER.

In short-base range finders the requirements for naval purposes are essentially different to those for field use. An instrument that is to be used in a stationary position in the fighting top of a battleship need not be a light instrument; indeed, weight adds very much to its steadiness when a stiff wind is blowing. In order that it may turn round in the least possible room, of course the vertical or azimuth axis has to be placed below its center; and in order to facilitate the keeping of a distant ship in the field of view, consistently with the least possible movement of the observer, it is essential that the eye-piece should also be at or near the center of the instrument and over the azimuth axis.

A photograph of the Cooke naval range finder on its stand is reproduced in Fig. 14, annexed. There is only one telescope, O H P L E (Fig. 15), whose objective (2¾-inch aperture) is at O, the halving prism and first lens of erecting eye-piece at H, a small optical square at P, erecting lens at L, and third and fourth lenses at E.

This elbowed telescope is attached to (and looks into) the right-hand box B2 at one end, and at the other end to the outer steel tube T at its middle. This outer steel tube carries within it the inner steel tube *t*, the supporting connection between them being only at the two ends, all connections and working parts being supported by the outer tube. This is done to save the inner tube from all capricious vertical buckling that can alter the halving adjustment. The end boxes B1 and B2, carrying the two optical squares S1 and S2, respectively, are fixed to the end of the inner tube.

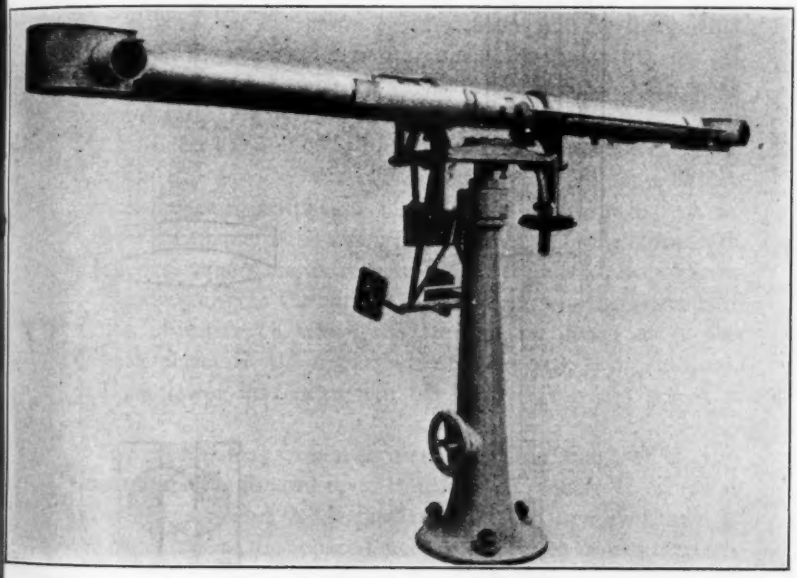


Fig. 14.

At C1 and C2 are two plane silvered-glass mirrors, large enough to take in the full beam of light filling the objective and turning the light through about 180 degrees. S *p* is the swinging prism, and Z *p* the zero setting prism. They are achromatic prisms, giving a minimum deviation of about ¾ degree, and are exact duplicates.

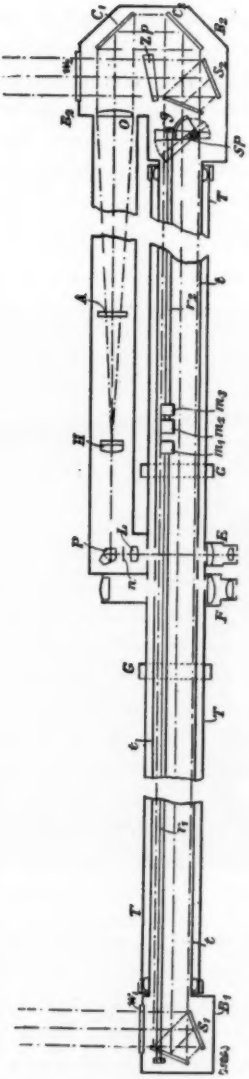


Fig. 15.

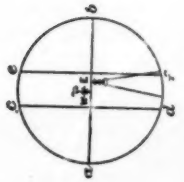


Fig. 18.

Fig. 17.

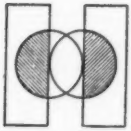


Fig. 16.

The single telescope performs its functions in this way, that the upper half of its object glass receives light from the distant object through the right-hand end of the base, and the lower half through the left-hand end. Taking the right-hand end first, the light from the distant object passes through the window W2, the zero setting prism Z*p*, is twice reflected from the upside-down optical square S2 (the bottom edges of whose mirrors are level with the center of the objective), and then off the upper halves of the two mirrors C2 and C1 into the upper half of the objective O, by which it is brought to a focus on the halving prism H, the image that falls upon the lower half of such halving prism being utilized, but the image that falls upon the upper half of the same being completely cut off by a screen *n* near L, where a double image of the (apparently) bisected objective is formed, as shown in Fig. 16.

At the left-hand end the light from the distant object passes through the window W1, is twice reflected from the larger optical square S1 and passes thence along the lower half of the inner tube through the swinging prism S *p*, then underneath the optical square S2, is reflected twice from the lower halves of the two mirrors C2 and C1, and thence into the lower half of the objective O, which then throws an image on to the halving prism H, the upper half of the image being utilized, and the lower half being cut off by the aforesaid screen *n* near L.

The erector lens L, then throws a reversed image of H, and the two images formed upon it, into the eye-piece E, where it is further magnified. The final result is that the view shown in the upper half of the apparent field is that which is seen through the right-hand window *w2* and the upper half of the objective, while the view seen in the lower half of the apparent field is that obtained through the left-hand window *w1* and the lower half of the objective.

Fig. 17 is a vertical section of the halving prism H, which is cemented to the achromatic first lens of the eye-piece, showing the fine edge separating the two half images which are formed by the different halves of the objective.

Fig. 18 is a view of the image finally seen in the eye-piece, *a b* being the halving line, and *c d* and *e f* two vertical guide lines (etched upon the halving prism), which are about 15 minutes of arc apart. All observations of coincidence are supposed to be made somewhere between these two lines or in the middle portion of the field, where definition is the sharpest. These guide lines also perform valuable functions in the first adjustments of the instrument. The field is illustrated with the split images in use, showing the two images abruptly cut off at the halving line. By operating the range prism S *p* the horizontal separation is neutralized.

When set on an infinitely distant object, such as the moon, the swinging prism S *p* is set to its position of minimum deviation, when it is about square to the rays of light passing through it, and deviates the rays through about three-fourths of a degree. Then the zero prism Z *p* is, by means of a suitable screw, swung round from its position of minimum deviation until the two images are in horizontal coincidence. In order that this may be done, the angle between the mirrors of the optical square S_2 is made about one minute less than the angle between those of S_1. This adjustment of the zero having been made, if the instrument is then turned upon an object at a finite distance—say, 7,000 yards—obviously the lower image from the left-hand end must then show to the right-hand side, and there is a horizontal separation of 1 minute 36 seconds between the two images, as in Fig. 18.

This parallax is now neutralized and measured by turning the knurled drum m_3 in the top of the tube upwards with the fingers of the right hand. This drum, through the tubular-steel rod r_2 terminating in a tangent screw *g*, works round the worm-wheel sector to which S *p* is attached. S *p* is thus swung round upon a vertical axis in the direction of the dotted position until it gives enough extra deviation to throw the lower image (as seen in the field of the erecting eyepiece) into strict horizontal coincidence with the upper image.

The correct range is then indicated upon a long ivory scale which travels to and fro in front of the upper part of the

finder eyepiece F. The rod r_2 has a quick screw of about 2-inch pitch, turned on its outside, whose function it is to traverse a nut, to which is fixed the ivory scale, so that the travel of the scale and the angular swing of S p are strictly co-ordinated.

It should here be pointed out that the device of neutralizing and measuring the parallax by means of swinging a prism away from its position of minimum deviation about an axis parallel to its refracting edge is the most delicate and unerring method that has yet been devised.

In the case of the swinging prism it can be shown that for an angular motion N the amount of extra deviation given by it is proportional to N^2, or the square of the angle of swing for the first 18 degrees of swing, after which an extra deviation varying as N^4 becomes perceptible. This means that its measuring capacity is much more delicate for the small parallaxes and long ranges than for the short ranges. This has certain very obvious advantages.

Now it is clear that certain temperature errors are excluded from this instrument, chiefly because there is only one telescope, and the only thing essentially necessary to its accuracy is the absolute invariability of the angles contained between the two mirrors constituting each optical square, or else, if there be variation, then they shall both vary the same way. For instance, if the reflecting angle of S_1 enlarges by one second on a cold day, then the lower image seen through it will go to the left hand in the field by one second; but the probability is that the change induced in S_2 will be the same (since the two optical squares are duplicates in construction), and also cause the upper image to move to the left, so that no range error will be produced. The writer has proved that the condition of non-variability of the two optical squares is quite within the possibilities of ordinary workshop practice. Their construction was explained in the last article.

The horizontal buckling of the inner tube cannot, of course, affect the coincidence of the images in the least degree, while the vertical buckling only affects the halving error, from which

no indirect error can follow, since the telescope looks into both optical squares from the same direction. No movements of the two reflectors C_1 and C_2 that can possibly take place can in the least degree affect the range readings, since, if they move, both images are shifted together, and coincidence is not affected. The temperature effect upon the refraction of S *p* is exceedingly minute (about 1 second for 50 degrees centigrade alteration of temperature), but what there is is neutralized by the equal variation that takes place in Z *p*. Variations in barometric pressure also affect the refraction of both prisms alike. No movements of any of the lenses of the telescope can affect the coincidence, since, if any one lens moves, then both images are shifted in the same direction.

A considerable and unlikely degree of wear of the worm sector and worm operating the range prism S *p* would be required to visibly affect the readings. For instance, if coincidence has been obtained for an object 7,000 yards away, then, should the angle of swing of S *p* be thrown wrong by one minute of arc, the effect upon the coincidence would be only 0.28 second; similarly it would be 0.14 second at 28,000 yards, about 0.35 second at 5,000 yards (the error consequent upon one minute of error in swing varying inversely as the square root of the range). It is thus seen that at 7,000 yards range the optical leverage, as it were, of the swinging prism S *p* is as 214 to 1. All backlash between the worm and worm wheel is, of course, taken up by a spring.

Doubtless, the telescope having to be carried in an exterior parallel tube detracts somewhat from the compact appearance of the instrument, but it does not interfere with the ease of manipulation. The two collars G and G, containing ball races, furnish the horizontal bearings in which the instrument turns for adjustment in altitude. These collars fix on to trunnions on the stand of the instrument. Every optical part is easily got at for cleaning, and every part of the telescope can be taken out altogether for that purpose. A is the astigmatizer lens, which is only brought into operation when distant bright lights are to be observed, when its employment turns the lights

into vertical luminous lines; or, instead of this, the screen *n* near L (Fig. 15) can be slid aside by pushing a knob to one side, when the split images are converted into the overlapping images, and two sets of lights, as seen through the right-hand and left-hand ends, respectively, can then be seen in any part of the field, and can be brought into coincidence by bringing one set directly below the other set, the field and its halving line and two vertical guide lines being illuminated for such work by means of a small electric lamp near the object glass. The use of the overlapping images is also almost indispensable for securing the first adjustment of the optical squares, so that the straight lines formed by the junction of their two reflecting surfaces may be parallel to one another and also perpendicular to the plane containing the base and distant object. Otherwise maladjustment in this respect will lead to small, indirect range errors should the inner tube buckle vertically under unusual sun heat.

Fig. 14 is, as already stated, a view of the instrument mounted on its stand. It will be noticed that the motion in azimuth is for the most part controlled by the hips, which are embraced between two teakwood cheeks, whose distance apart can be easily adjusted. The left hand works the instrument in altitude by means of the handle shown hanging downwards, while the right hand is placed on the top of the instrument and operates the drums m_1, m_2, m_3 (Fig. 15) regulating the halving adjustment and the rotation of the range prisms.

These three knurled drums are in three separate compartments, the left-hand one (from the observer's point of view) regulating the halving error by causing the optical square S_1 to swing slightly upon an axis pointing to the distant object. The middle one is a quick motion for approximate range reading, and the right-hand one is for the final setting of the horizontal coincidence or range reading. The ivory scale giving the ranges is about 30 inches long, and is seen and read in the upper part of the field of the finder telescope, which carries a small pointer.

The trunnions on which the range finder is securely fixed are

mounted on spiral springs and linkwork in order to isolate the instrument against the vibration so often prevailing on board ship.

The height of the instrument can easily be altered to suit the height of any observer by simply turning the wheel shown near the base of the pillar. In order to guard sufficiently against interior atmospheric refraction, the inner tube is covered with one layer of flannel and one layer of leather, while the outer tube and boxes are covered with waterproof leather; but in the case of the sides of the boxes a small air space is left between the leather and the cast iron of which they are made. This latter precaution is required in order to guard the optical squares inside from unequal temperatures under sun heat, for, should the metal frame across the front or open end of the optical square be 1 degree centigrade warmer than the other end, an error in reflection of $2\frac{1}{8}$ seconds might be produced. However, careful experiments have satisfied the writer that under the hottest sunshine, from above or behind, no greater difference than about $\frac{1}{3}$ degree to $\frac{1}{2}$ degree centigrade could arise, and this would be partly neutralized by a corresponding error in the other optical square. But under sun heat from the front, directly or indirectly causing heat to be radiated in through the window of the left-hand optical square more especially, the local and temporary warming up of the front end of the latter is almost sure to follow, leading to the lower image from that end moving towards the left by 1 to 3 seconds, causing longer readings to be obtained, unless the precaution is taken of forming the tubular sunshades of a double tube, with about a quarter-inch of space between, that is left open to the air. Even then sun heat nearly in front is apt to get reflected obliquely off the interior surface of the inner tube, and thence on to the front part of the optical square frame. Altogether it seems to be impossible to devise an instrument that shall be always absolutely unaffected by one-sided radiant heat, and therefore shading of some sort is always desirable, for in no other way can the uniform temperature of the optical squares be secured.

Lastly, it may be pointed out that after this instrument has once been accurately corrected for zero in the workshop there is no reason why it should ever require readjustment afterwards, unless the instrument meets with violence or is meddled with. The new Cooke military range finder for artillery purposes has, of course, to meet special conditions other than those obtaining in the Navy.—"Engineering."

THE BRITISH ARMY AEROPLANE.

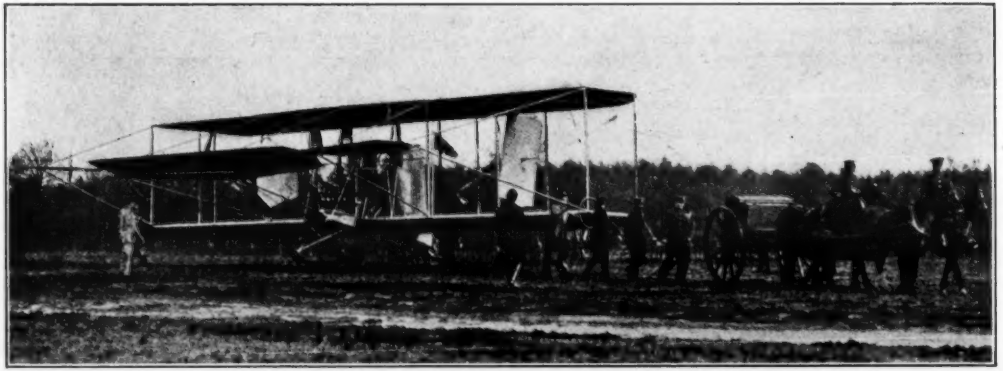
After carrying on a series of experiments last September and October, the aeroplane designed by Captain S. F. Cody, of the British Aeronautical Corps, was remodeled and has lately been given some further trials.

As first designed, this machine was similar to the present aeroplane. The dimensions of the planes were 40 feet long by 7½ feet wide, and they were spaced 8 feet apart. Movable-wing tips were arranged at the ends of the lower planes, the horizontal rudder being placed in front and the triangular vertical rudder at the rear. There was also a small triangular vertical surface above the main plane at the center. The flights made by this machine were 304 feet on September 29, 200 feet at 10 feet elevation on October 14, and 1,200 feet at 30 feet elevation in 27 seconds on October 16. In the last flight the machine tipped to one side and was smashed when it struck the ground.

The planes of the new machine are about one-third longer than those of the old one, and the total weight of the machine is some 1,500 pounds. The same 50-horsepower 8-cylinder Antoinette motor is used. It is placed at the front of the lower plane in the center, and drives two peculiar propellers located each about 4 feet on either side of it at the front edge, by means of chains. The movable-wing tips have been placed beside the horizontal rudder, so that they are practically extensions of it. One of these turns upward and the other downward when the steering column is swung from one side to the other, while a

forward-and-backward motion of the steering column turns the horizontal rudder. The vertical rudder is placed at the rear, as before, and is worked by turning the steering wheel. The 3-gallon gasoline tank is placed above the motor, and the radiator is located vertically behind the aviator's seat, which is back of the motor. The motor is mounted upon a substantial chassis and strong springs are interposed between this chassis and the axles of the running gear for the purpose of absorbing the shock when the machine strikes the ground.

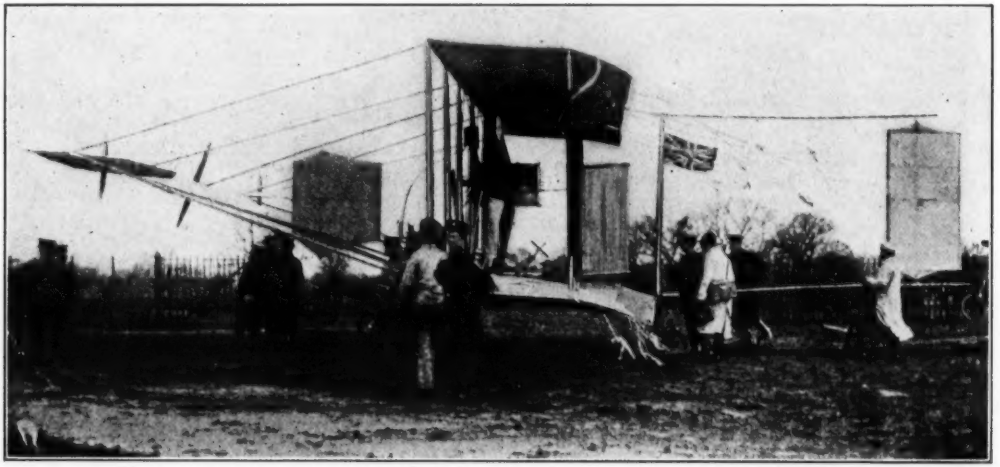
The most notable feature of this aeroplane is found in the two propellers. These are of a peculiar type, similar to that described in the "Supplement" of December 19, 1908, by Mr. Sidney H. Hollands. The peculiar feature is that the blades are broader at their base than at their ends, the width at the base being 24 inches, and the width at the outer end being but 5 inches. The length of the blades is about 3 feet. They are made of aluminum and are curved somewhat like a sugar scoop. Each one is mounted on a strong piece of steel tubing. Mr. Cody, as well as Mr. Hollands, both claim to have found that a blade of this shape gives better results than the usual form of blade, which is narrower at the base than at the tip. It is only in this respect that Mr. Hollands' propeller resembles that used by Mr. Cody on the British Army aeroplane. In a letter to English "Aeronautics" Mr. Hollands describes his propeller (with which he claims to have obtained a thrust of 26 pounds per horsepower) as having two "narrow-tipped blades of a special conchoidal (or irregular-crescent shape) cross-section, set to pitch angles of maximum efficiency. These angles, together with the other foregoing essential features, were all separately determined by a long and careful series of comparative experiments. The blades have a twist, and the pitch is 0.7 of the diameter. It is most efficient at high speeds (the driving torque being relatively very small), and the essential features of the design lend themselves to strength and rigidity. It is constructed wholly of high-grade steel, and the two meters, diameter type, weigh 13 pounds, with a factor of safety of six, at 1,200 revolutions per minute." Mr. Hol-



THREE-QUARTER FRONT VIEW OF THE AEROPLANE.

The movable tips at each end of the horizontal rudder, the motor and propellers, the three-wheeled chassis with buffer wheel in front, are all visible in this photograph.

THE NEW AEROPLANE OF THE BRITISH AERONAUTIC CORPS.



END VIEW OF THE BRITISH ARMY AEROPLANE.

Note the vertical rudders in the front and rear, the propellers and motor at the front edge, and the vertical gasoline tank and radiator between the planes at the center and toward the rear. The flag and streamers show the direction of the wind.

THE NEW AEROPLANE OF THE BRITISH ARMY AERONAUTIC CORPS.

lands claims that his propeller is superior to those used on the Army aeroplane, and that it was designed some years before the propellers of Mr. Cody.

According to a cable report, the first test of the remodeled aeroplane occurred on the 20th instant. Two short flights were made by Captain Cody successfully, but the third one was terminated, after the machine had traveled some 300 feet at a height of about 20 feet from the ground, by the buckling of the horizontal rudder, and the aeroplane fell heavily and was badly wrecked.—"Scientific American."

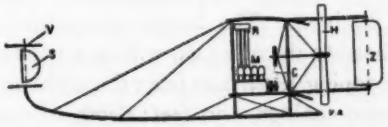
THE WRIGHT AEROPLANE.

From "La Vie Automobile," translated by E. N. JANSON.

The sketch shown herewith shows the principal features of the aeroplane which bears the name of its inventors—the Wright brothers—of which a great deal has lately been published in the daily press of almost every country.

In the sketch the aeroplanes proper are represented by the heavy black lines. Other parts are designated as given in the following lettered memorandum:

M is the motor (gasoline), R is the cooler, C is the screw-propeller transmission or driving chain, H is the screw propeller, Z are the rudders (balanced), S are two vertical stability planes, V are two horizontal stability planes, one over and the other under S.



As shown in the sketch, all surfaces are arranged in double units. The rudder S consists of two parallel planes, which are turned simultaneously by a vertical rudder stock. This is placed between the two planes and is shown dotted in the

figure. The forward stability planes are stationary and cannot be turned. Through some peculiar action those planes prevent the overtipping sideways of the machine, and thus perform duty similar to that of the tail of an ordinary kite. The planes marked V are movable and in their function elevate the machine upwards or downwards.

The dimensions of some experimental machines are as follows:

Surface of aeroplanes, square feet	54
Span (from edge to edge), feet	40
Weight, total, pounds	880
Motor power, H.P.	25
Cylinder diameters, inches	4¼
Stroke, inches	3.9
Weight of motor, inches	218
Weight per H.P., pounds	8.72
Diameter of propellers, feet and inches	9–3
Revolutions per minute	450

THE DRYDOCK FOR THE PEARL HARBOR NAVAL STATION, HAWAII.

The concrete drydock for the Pearl Harbor Naval Station, Hawaii, for the construction of which the Bureau of Yards and Docks will open bids on February 13, will be the largest ever constructed by the Navy Department. Its over-all length will be 1,195 feet, as against 799 feet over all for the longest dock previously constructed, located at Philadelphia, and against 863 feet over all for the Puget Sound drydock, recently placed under contract. The length from the inside of the coping at the head to the outer sill will be 1,152 feet; the width over all at the coping level, 140 feet; the width in the body of the dock between copings, 130 feet; depth of water on sill at mean high-water level, 35 feet. The walls and floor will be constructed throughout of concrete, but granite lining will be used for the caisson seats, the coping at the entrance and the material slides. The conditions for the use of concrete are believed to be more favorable at Pearl Harbor than at any

point in the United States, on account of the equable climate and absence of frost.

The design includes a number of departures from the practice of the Navy Department, principal of these being the provision for dividing the main structure into an inner and an outer dock. There will be four caisson seats, two as usual at the entrance and two near the middle, giving an outer dock with a clear length between inside-caisson seats of 575 feet and an inner dock with a clear length from the inside of the coping at the head to the inside-caisson seat of 532 feet. There will be two steel caisson gates, and the arrangement will be such that with a ship in the inner dock the outer dock may be filled and emptied independently, thus allowing the ship upon which the most extensive repairs are to be made to remain in the inner dock. With this type of head the over-all length docked in rapid succession in the outer dock. By floating the inner caisson from the drydock ships of greater length than any now in existence or planned could be docked, while, with a depth over the sill at mean high water of 35 feet, the largest present battleships may enter the dock at any stage of the tide in Pearl Harbor. This depth, it may be noted, will be the second largest in the Navy's docks, the only greater one being the proposed structure at Puget Sound, where the great variation in tide required a draught of 38 feet.

Another innovation is a new type of trapezoidal form of head, so arranged that three destroyers may be docked side by side, extending to the very head of the dock, leaving room for three other small craft behind them in the inner dock. With this type of head the over-all length of the dock would be 1,191 feet, whereas the length above given, 1,195 feet, is for a V-shaped head. Bids will be received on these two types of head and also on an arch shape, with a radius on the inside of the coping of 128 feet. With this type of head the over-all length would be 1,183 feet, though the length from the outer sill to the inside of the coping at the head would be increased from 1,152 feet, as in the other forms, to 1,160 feet.

One of the marked differences between the proposed dock

and those previously constructed is that the working floor will not only be absolutely level from end to end, but will be free from the usual obstructions, such as bilge-block and docking-keel block bearers and bilge-block chains. This will be accomplished by making the bearers or slides of hollow cast-iron box section and imbedding them flush with the floor. The wide flanges on top will form the bearers for the blocks, and a slot will be used to take the anchor bolt for the keel blocks and the holding-down device for the bilge blocks. The cast-iron boxes are large enough also to take the chains for hauling the bilge blocks across the floor of the dock while the ship is being placed.

Another important function of the cast-iron boxes is to drain the floor, the water passing through the slots and along the sloping bottoms into four large longitudinal sub-floor drains. These, in turn, carry the water into the drainage chamber near the middle of the dock, the two parts of which have independent drainage systems. Three 54-inch pipes, fitted with gate valves, carry the drainage from each system into a common wet chamber, from which suction pipes run to a common pump well located opposite the middle of the dock.

The floor drains will also be used for filling the dock through four filling culverts, located in the quay wall, which are connected with the longitudinal drains in such a manner that either the inner or outer dock may be filled independently of the other. The water will be discharged into the dock with an upward velocity, and, being very nearly uniformly distributed over the entire floor, will not cause any harmful movements of the ship, such as may occur when water enters at the ends or sides with a considerable velocity.

The bottom of the dock will be reached by 16 flights of stairs, and material slides have been placed at convenient intervals. The pump well has been designed so that it can be utilized at a later date for another dock which would be located on the other side of the well, opposite to the present one. A track for a 40-ton crane will be built around the drydock structure, with the inner rail on the coping. The construction

will require the removal of 350,000 cubic yards of material, which will be utilized in filling some of the low areas on the Naval Station property. The depth of the excavation will be 58½ feet. The total amount of concrete will be approximately 120,000 cubic yards, and most of it will be mixed with 1 cubic foot of Portland cement to 6½ cubic feet of broken stone, combined with a variable proportion of sand, depending on the voids in the stone.—"Engineering Record."

THE FLEETS OF THE MARITIME POWERS.

Sea Strength of the Leading Powers.

The following information has been compiled by the Naval Intelligence Office, under date of November 1, 1908. The vessels not included in the tables are those over twenty years old, unless they have been reconstructed and rearmed since 1900; transports, colliers, repair ships, converted merchant vessels, or any other auxiliaries; vessels of less than 1,000 tons, except torpedo craft; torpedo craft of less than 50 tons. The table showing the vessels building or authorized includes those authorized but not yet laid down, as well as those

VESSELS BUILT.

Country.	Battleships.	Armored cruisers.	Cruisers.	Destroyers.	Torpedo boats.	Submarines.	Coast defence vessels.
	(*a*)		(*b*)				(*c*)
England	52	35	86	144	48	44	0
France	18	21	26	44	256	44	11
United States	25	12	39	16	32	12	11
Germany	22	8	37	64	42	2	8
Japan	11	11	19	55	63	10	3
Russia	5	5	15	93	57	25	4
Italy	11	6	10	17	61	5	0
Austria	3	3	5	6	35	0	6

(*a*) Battleships, first class, are those of (about) 10,000 tons or more displacement.
(*b*) Includes all unarmored cruising vessels above 1,000 tons displacement.
(*c*) Includes smaller battleships and monitors. No more vessels of this class are being proposed or built by the great powers.

VESSELS BUILDING OR AUTHORIZED.

Country.	Battleships.	Armored cruisers.	Cruisers.	Destroyers.	Torpedo boats.	Submarines.
England	*a* 7	4	7	25	23	26
France	6	2	0	30	10	55
United States	6	0	0	15	0	15
Germany	*b* 9	3	6	21	0	4
Japan	4	*c* 2	3	4	0	2
Russia	8	2	0	4	0	6
Italy	6	4	1	0	2	12
Austria	3	0	1	6	10	6
Brazil	3	0	2	10	0	3

a England has no continuing shipbuilding policy, but usually lays down each year four armored ships, with a proportional number of smaller vessels, although during the current year this number was reduced to two armored vessels.

b Germany has a continuing shipbuilding policy, authorized by the Reichstag, and extending to the year 1917. This authorization provides for the building between 1907 and 1917 of 16 battleships, 12 armored cruisers, 22 smaller cruisers and 132 torpedo vessels.

c Reported that two more are authorized.

actually under construction. In making comparisons of naval strength, and particularly of naval increase, the fact should be considered that the rapidity of construction varies materially in different countries. In England, Germany and Japan battleships and armored cruisers are completed in two to three years; in the United States in from three to four years, and in France, Italy and Russia not less than four years are required.

Relative Order of Warship Tonnage.

The present warship tonnage of the principal powers as given by the Office of Naval Intelligence is as follows:

	Present tonnage.
Great Britain	1,669,005
United States	685,426
France	628,882
Germany	524,573
Japan	371,891
Russia	240,943
Italy	220,458
Austria	114,250

Personnel of the World's Fleets.

Under date of November 1 the Office of Naval Intelligence has compiled statistics showing the strength of the personnel of the principal naval powers, as shown in the accompanying table.

	England.	France.	Germ'ny.	Japan.	United States.
Flag officers	96	45	33	53	*a* 18
Captains and commanders	610	355	258	259	*a* 182
Other line officers and engineers *b*	3,268	1,802	1,719	1,798	795
Medical officers	501	*c* 377	210	*c* 318	296
Pay officers	571	201	205	277	201
Warrant officers	*d* 1,987	*e* 1,793	2,036	1,404	604
Enlisted men	99,319	44,577	*f* 47,286	41,966	42,400
Marine officers	520	.....	103	.....	268
Enlisted men (marines)	17,844	.....	1,365	.....	9,293

a The United States now has, in addition, temporarily, as extra numbers, due to promotion for war service, 6 flag officers, 13 captains, 10 commanders, 12 lieutenant-commanders and 6 lieutenants.
b Does not include midshipmen.
c Includes pharmacists and apothecaries.
d Includes chief gunners, chief boatswains, chief signal boatswains, chief carpenters, chief artificer engineers, chief schoolmasters and head schoolmasters.
e Includes adjutants, maitres and premier maitres of all branches.
f Includes 1365 men of the naval infantry.

From this table it is evident at a glance that the United States Navy is weakest in flag officers, captains and commanders, especially the two former, and every one familiar with the routine operations of the Bureau of Navigation is aware of the difficulty growing out of the shortage of officers in the higher grades. With 53 flag officers, Japan, which at present ranks fifth in warship tonnage, has as many in that grade as the United States and Germany combined, although these nations rank ahead of Japan in tonnage.—"The Navy."

ENGLISH NAVAL NOTES.

New Ships.—The new first-class battleship to be laid down at Portsmouth this month is to be named the *Neptune*. It is reported that she will be 10 feet longer and have 2 feet more beam than her predecessors, so that she will be 510 feet long,

with a beam of 86 feet; her displacement will be 20,250 tons, and her turbine engines are to develop 25,000 I.H.P.

The new first-class cruiser to be laid down at Devonport is to be known as the *Indefatigable,* and is to be commenced in February. She is to be an improved *Indomitable,* and the following are believed to be her approximate dimensions:

	Indomitable.	*Indefatigable.*
Length, ...	530 ft.	570 ft.
Beam, ...	78 ft., 6 in.	79 to 80 ft.
Displacement, ...	17,250 tons.	18,000 tons.
Horsepower, ...	41,000.	45,000.
Speed, ...	25 knots.	28 knots.

In view of the great improvement of the new ship over her three predecessors, it will probably be found that two more of the same type will in due course be built, so as to have a group of three of these ships.

The largest cruiser at present building abroad is the German "*F*," reported to be of 18,700 tons displacement, to carry an armament of twelve 11-inch guns, with turbine engines to develop 45,000 I.H.P.—"J. R. U. S. I."

H. M. S. Vanguard was launched from the yard of Messrs. Vickers, Sons & Maxim, at Barrow, on Monday. In accordance with the policy now adopted by the Admiralty, the available details of the new battleship are meager, but the *Vanguard* is described as an improvement upon the *Dreadnought* in several ways. She is 1,350 tons heavier, 10 feet longer and 2 feet broader. In the first vessel were several weaknesses, and these have been remedied in the later vessel. The transverse bulkheads have been extended, as a better protection from submarine mines, etc. The keel of the *Vanguard* was laid on April 2d last year, and it is a matter of great congratulation at Barrow that the vessel should be ready for launching so soon and in such an advanced state. Her launching weight was close upon 10,000 tons. When complete she will displace 19,250 tons. She is 500 feet long, with 84 feet beam, and her

horsepower, with which it is expected to attain 21 knots, is 24,500. She will carry ten 12-inch guns and twenty 4-inch. The weight of projectile from the heavy guns will be 850 pounds. Her protection consists of 11 inches, with 4-inch belting, 2¾-inch decks. The upper belt is 8 inches to 6 inches, while the big-gun positions are 12 inches to 8 inches. She will have a complement of 800 men. The *Vanguard* is the largest vessel ever built at Barrow, although the Brazilian battleship, which is now on the stocks there, is of even larger dimensions.

Another naval event of considerable importance this week is the commencement of the *Indefatigable* at Devonport Dockyard. She is to create a record in cruiser construction, and will have a displacement approximating to 19,000 tons. The contract speed of the *Indefatigable* is said to be 28 knots, but having regard to the fact that the actual speed of the *Invincible* is between 26 and 27 knots, although nominally 25, it is quite conceivable that the new vessel will realize nearly 30 knots. It is proposed to advance the ship to launching stage in seven months.

The battleship Bellerophon, having just been commissioned at Portsmouth, takes up her position in the Home Fleet at the Nore, where she replaces the battleship *Victorious,* which will be reduced to nucleus crew. The *Bellerophon* possesses several improvements in the matter of general equipment, range of fire and fire control, her electrical installation being far in advance of that of any ship afloat. She carries a complement of 870 officers and men. The *Bellerophon* is 490 feet long, 82 feet beam, and when drawing 27 feet has a displacement of 18,600 tons. The machinery is of the Parsons steam-turbine type, and was constructed by the Fairfield Shipbuilding and Engineering Company, Ltd., Govan, N. B.

The keel plate of the new cruiser *Indefatigable,* which will be the largest and most powerful cruiser in the world, was laid down at Devonport Dockyard by Mrs. Cross, wife of the

Admiral Superintendent of the yard. The cruiser will be launched in October next. She will have a displacement of 19,000 tons. It is stated that she will be fitted with internal-combustion engines.

Preparations are being made for laying down a new ship at Pembroke Dockyard early in the next financial year. The type of the new vessel is not definitely known, but it is believed that she will be a replica of the cruiser *Bellona,* which is to be launched from Pembroke on March 20th. It is stated that a similar vessel will be laid down at the same establishment later in the year.

On Saturday afternoon H. M. S. *Superb,* which has been built by Messrs. Armstrong, Whitworth & Co., left the Elswick Shipyard for a berth lower down the river. The vessel was under her own steam, but was accompanied by five powerful steam tugs.

After undergoing refitting operations at Portsmouth, during the past two months, H. M. battleship *Dreadnought* sailed for the Nore to resume her duty as flagship of the Commander-in-Chief of the Home Fleet.

In view of the performances of the *Mauretania* and the fact that her turbines were produced by the Wallsend Slipway and Engineering Company, very sanguine expectations are entertained concerning the battleship *Superb,* which has just left Elswick, the turbines of this vessel being from the works of the same company. The engineering strike on the North East Coast somewhat delayed the completion of the new battleship, which, as our readers will remember, was launched on November 7th, 1907. The *Superb* has a displacement of 18,600 tons. She carries ten 12-inch guns in pairs in five hooded barbettes, one on forecastle, one abaft the funnels on the same deck, one aft on upper deck, and one on each bow on the upper deck; the armament also includes twenty quick-firing 4-inch guns and five torpedo tubes. Her armor consists of a complete Krupp steel belt, 11 inches, tapering to 6 inches forward and 4 inches aft.—"Page's Weekly."

Naval Base at Rosyth.—The Secretary of the Admiralty announces that a contract for the new naval establishment at Rosyth has been let to Messrs. Easton, Gibb & Son, Limited, contractors, Westminster. The contract is divided into two sections, the first of which, comprising a submarine depot, boat slip, pumping station and electric-power house, is to be completed in four and a half years. The second section, which includes the remainder of the work, comprises a large basin, having an area of over 50 acres; an entrance lock, available for use as a dock, 850 feet long, 110 feet wide at entrances, and 36 feet deep over sill at low-water spring tides; a dock 750 feet long, 100 feet wide at entrance and 36 feet deep over sill. This dock, which is entered from the basin previously mentioned, will be so constructed that it can be subdivided for use as two separate drydocks, and provision is made for lengthening it up to 1,000 feet. The entrances to the dock, lock and basin will be by means of sliding caissons. These latter are not included in this contract, and the designs for them are not yet completed. In addition to the usual equipment, such as bollards, etc., the contract includes a considerable amount of dredging. The second section of the contract is to be finished in seven years, a substantial bonus being paid in the event of earlier completion. Although the scheme, as now approved, is complete in itself, care has been taken so to arrange it that it can at any future time be extended without interfering with anything which is done now. Besides an additional basin, a number of docks of the largest size can be readily constructed, in addition to all the shore requirements for a first-class naval port. The Admiralty have already expended a considerable sum at Rosyth in erecting staff offices and dwellings, the provision of water and sewage services, and in the sinking of a trial caisson in the bed of the Firth for the purpose of ascertaining the nature of the strata to be dealt with in the course of the excavation of the dock and the sinking of the monoliths or caissons which will form the foundations for the walls. The trial cylinder was sunk by the firm of Sir John Jackson, Limited, to a total depth of 101 feet below the sea bed. The

cylinder is stated to have been 8 feet external diameter, and the results of the experiment show that the strata consists in the main of glacial boulder clay. Numerous trial borings have also been sunk and road diversions carried out. A branch railway has been constructed to connect the works with the N. B. Railway. The large graving dock, which will be 750 feet long at coping level, with an entrance width of 100 feet, is to be constructed with a temporary end so that it can be lengthened at any time to 1,000 feet.—"The Engineer."

FRENCH NAVAL NOTES.

Vice Admiral Germinet's Supersession.—Vice Admiral Germinet has been relieved of his command of the Mediterranean Fleet, and his flag was struck at sunset on the 7th ult. on board his flagship the *Patrie*. The Admiral was summoned to Paris on the 3d ult. by the Minister of Marine to give explanations as to certain statements which had appeared in the press, and which it was stated were made by his authority, as to various deficiencies in the fleet under his orders, and in particular in regard to the dangerous shortness of ammunition for the Navy which existed and which had existed for some years past, and, although the true state of affairs was well known at the Ministry of Marine, no steps had been taken to remedy it. Explanations were also called for from the Admiral in regard to the circumstances under which the armored cruiser *Condé* had grounded off Ajaccio during the recent maneuvers. Vice Admiral Germinet had interviews with both M. Picard, the Minister of Marine, and M. Clemenceau, the Premier, but his explanations were not considered satisfactory, and as the result it was decided to relieve him of his command, an order to that effect being signed by the President on the 5th ult.

The incident has naturally caused a great sensation, as the facts as stated by the Admiral are admitted to be perfectly true, especially as regards the serious depletion of the reserves of ammunition. The incident was the subject of an animated

debate in the Chamber, and in view of Admiral Germinet's high professional reputation and the admittedly unsatisfactory state of things existing in the Navy, it seemed at one time as if a hostile vote would be recorded against the Government, but this was avoided on a promise being made to lay before Parliament at an early date a complete exposé of the state of the Navy, as well as a carefully prepared plan of reorganization and satisfactory proposals for a new building program.

The withdrawal of Admiral Germinet from the command of the Mediterranean Fleet is much regretted, and is felt as a distinct loss in the Service, for he is a very able officer, a good tactician and disciplinarian, and at the same time extremely popular with all ranks. He was appointed to the command of the Mediterranean Fleet, in succession to Vice Admiral Fournier, on November 5th, 1907, and during the thirteen months he has held the command has admittedly brought the fleet up to a very high standard of efficiency.

The New Commander-in-Chief of the Mediterranean Fleet.—Vice Admiral De Fauque de Jonquierès, who has been selected to succeed Admiral Germinet in command of the Mediterranean Fleet, is, although he is well up on the list of Vice Admirals, the youngest but one on the list, and is in his 59th year. He comes from a well-known naval family; his father was an officer of high distinction, who held various important appointments. The new Commander-in-Chief entered the Service in 1867, and as a lieutenant, when in command of the gunboat *Aspic,* much distinguished himself at the battle of Foochow on August 4th, 1884, where he led the gunboat division, for which service he was promoted to capitaine de frégate. As commander of the *Inconstant* in 1891 he took a leading part in the suppression of the disturbances in the basin of the Yangtse-Kiang, for his services on which occasion he received a warm letter of thanks from Sir F. Richards, at that time the English Commander-in-Chief in China. He was promoted to captain in 1892, and ten years later became a rear admiral. After serving in the Ministry of Marine he was appointed second in command of the China Squadron, where

he displayed great tact in dealing with Admiral Rodjestvenski during the sojourn of that officer with his fleet off the coast of Cochin-China. On his return to France he was nominated Naval Attaché at Berlin, where he soon made himself extremely popular, and won the regard of the Emperor William in a remarkable way. Promoted to vice admiral in July, 1907, he was almost immediately afterwards, on the death of Vice Admiral Melchior, appointed Member of the Superior Council of the Navy and Inspector General of Torpedo and Submarine Flotillas. His selection for the Mediteranean command has met with universal approval in the Service, for his reputation is as high as that of his predecessor, and he commands the universal confidence of officers and men alike.

French Armored Cruisers.—In a recent number of "La Vie Maritime," the editor, M. Charles Bos, who has twice served as reporter of the Naval Estimates to the Chamber of Deputies, and is a recognized expert writer on naval affairs, has been criticising somewhat unfavorably the French armored cruisers. According to the writer, the eleven old armored cruisers *Jeanne d'Arc, Amiral Gueydon, Montcalm, Dupetit Thouars, Gloire, Marseillaise, Condé, Amiral Aube, Dupleix, Desaix* and *Kléber* are unsatisfactory, both in regard to armament and speed. All these ships, according to their designs, should have a speed of 21 knots, the *Jeanne d'Arc* having been intended for 23. This latter ship, in spite of numerous alterations, has never exceeded 21.7, while the remainder even on their trial trips barely made 21, a speed which on service sank to 18 and even as low as 16, if there was anything of a sea on. In bad weather these ships are always coming to grief, and what they have cost in repairs must be terrific.

Yet in these eight armored cruisers, for we do not count the *Dupleix* and her two sisters—vessels of only 7,700 tons—armament, protection and strength of hull have all been largely sacrificed to obtain a speed, which has been unobtainable, and the vessels will not stand comparison with similar ships in foreign navies. Including repairs, each of these ships must have

cost between 28,000,000 and 30,000,000 of francs (£1,120,000—£1,200,000).

The new large armored cruisers *Léon Gambetta, Victor Hugo, Jules Ferry, Jules Michelet* and *Ernest Renan* are, however, much better; but even these are only on a par with the English *Drake* class, and are much inferior to the later ships of the *Warrior* and *Minotaur* classes—to say nothing of the *Indomitable* and her sisters—and to the German *Scharnhorst.* Moreover, these ships have cost more than any battleship anterior to the *Suffren,* including that ship, and not very much less than the battleships of the *Patrie* class, while they have far less protection and far weaker armaments, both of which have been sacrificed to speed.

In order to have these fast, but weakly-armed and badly-protected ships, at a time when we only possess a small number of battleships, we have expended more than 520,000,000 francs (£20,800,000); for ships, in fact, which could only in the last extremity be placed in the battle line, and which nobody knows how rightly to use, we have thrown into the sea something like half a milliard francs (£20,000,000). For the same money we could have had two fine squadrons of battleships, analogous to the six of the *Patrie* class, at a cost of about 42,000,000 francs (£1,680,000) each, although this cost might have been decreased by two or three millions (£80,000—£120,000) if they had been built in groups of three at four different dockyards. The difference in cost between these twelve battleships and the 520,000,000 devoted to the armored cruisers—including the *Sulley,* which has been lost—would have enabled half a score of scouts of high speed to have been added to the fleet, a class of vessel of which we have none.

There is not a single naval officer who would hesitate to say that our naval forces would be a great deal more formidable if they were composed of 18 first-class batleships of the *Patrie* class, and 10 fast scouts, than with the 6 *Patries* and the armored cruisers of which they can dispose at the present time.

As a matter of fact we were right when we wrote some time back that the armored cruiser is not a battleship, and that

sooner or later it would be one and the same thing with the battleship, to which greater displacement and higher speed has been given. The English *Invincible* and the Japanese *Tsukuba* show how rapidly the fusion of the two types is proceeding, for these ships by their armament are really extremely fast battleships.—Précis from "La Vie Maritime."

The French Naval Budget Report.—The report which M. Chaumet, the Deputy for Bordeaux, has just presented with regard to the French naval budget for 1909, is by no means of a nature to gladden the hearts of Frenchmen generally. M. Chaumet has the welfare of the French Navy at heart; it is, therefore, only natural that he should see its shortcomings very clearly, and he is led to say, "It is true we have a Navy—on paper." M. Chaumet examines carefully the items forming the French Navy; he shows that France has the following fighting-fit units: 15 battleships, 5 coast-defense vessels, 21 armored cruisers, 64 destroyers, 162 torpedo boats, 30 submersibles and 38 submarines. These figures are in striking contrast with the number of units which are supposed to be fit for actual warfare.

But M. Chaumet goes on to say that even the units mentioned are not realy so effective as they seem to be, for they are not provided with spare stores, and they have not even the requisite provision of projectiles. M. Chaumet sees a terrible danger to France in the inadequate measures taken for a rapid mobilization of the Navy, for weeks would be lost when an hour's delay might decide the fate of the country, and he refers to the two chief naval bases, Toulon and Brest, which are in need of costly and immediate improvements. The report resembles that of last year, in that it comes to the same conclusion, namely, the necessity for organically reforming the Navy.

M. Picard, the new Minister of Marine, began at once to introduce certain measures of economy into the arsenals and in the clerical staffs. He is supported by M. Chaumet, who recommends economy in men and material by doing away

with obsolete warships, by abolishing naval depots in distant countries, by doing away with the naval ports of Rochefort and Lorient, and by reforming the arsenals so that their output may be more in keeping with the cost of their upkeep.

With regard to the crews, M. Chaumet supports M. Thomson's project, which gives the "inscripts" the benefit of the "two-year law," and he is in favor of suppressing the "permanent year," and the depots of equipages of the fleet, which would set free 3,344 officers and men and result in the sum of £111,063 being saved.

Then M. Chaumet would like to combine the naval artillery with naval construction, so that engineers would be able to specialize for artillery construction as they specialize in other branches of their work.

It is well known that France has lost gradually her rank of second place on the list of great naval Powers. M. Chaumet says this has come about through two "wrong ideas"—first, France thought it ought to possess a defensive navy; and, secondly, France thought a navy could be had at cheap rates. The first idea led to a number of useless units being built. Now these units cost less than do battleships, but they last only half the life of battleships, and thus they are costly, after all. Then, the cost of the crews serving in these supposedly cheap flotillas is £627,005 a year, as compared with £491,365 spent annually on the crews of all the French battleships.

M. Chaumet makes a very interesting comparison of the foreign navies in 1920. Although in 1910 the French Navy's tonnage in battleships and armored cruisers will be still greater than that of Germany, yet, if it is to maintain its equality with Germany, France must have in 1918 a total tonnage of battleships and armored cruisers of 753,000 tons—that is, an increase of 350,400 tons, as compared with the tonnage this year. But before 1918 the tonnage of obsolete warships struck off the lists will be 105,500 tons; thus, this means that 455,000 tons of new warships will have to be built at a cost of £40,000,000, or at an average yearly expenditure of about

£4,400,000. M. Chaumet asks, Is France justified in making such an outlay?—and he leaves it to the French Government to provide a fitting solution.—"The Engineer."

The New Director General of Naval Artillery.—As the result of the numerous gun mishaps, some of a very serious nature, accompanied by heavy loss of life, which during the last three or four years have occurred in the French Navy, and of the continually recurring friction between the military officers controlling the Ordnance Department and the responsible naval authorities, M. Thomson, the Minister of Marine, shortly before his resignation, decided on the creation of a Naval Ordnance Department (Le Direction Centrale de l'Artillerie Navale), and appointed Rear Admiral Le Bris as the first Director General. The new department is constituted on the same lines as that of the Naval Construction, and consists of a central department and a technical section. Rear Admiral Le Bris is invested with complete and absolute authority over the chief of the technical section, the ordnance branches, the pyrotechnics and powder magazines at the ports, the Central Laboratory, the Experimental Commission at Gavres, the Ordnance Factory at Ruelle, the Gunnery School, the gunnery training of the men and firing practice of all the fleet in commission. All the personnel attached to these different services depend entirely upon him; in a word, the Admiral becomes the supreme head of the Naval Artillery.

Rear Admiral Le Bris is the youngest officer on the flag list, being only in his fifty-third year, having reached his present rank last June. He has the reputation of being the best gunnery officer in the Service, and was for some time in command of the sea-going gunnery training-ship *Pothuau.*

A decree in the "Journal Officiel" pronounces the abolition of Nouméa, New Caledonia, as a fortress and *point d'appui* of the fleet. Nouméa was declared a *point d'appui* by a decree of November 3d, 1905, less than three years ago, but recently opinions have completely changed as to its strategical value.

The Commission of the Budget of the Navy had decided to

recommend the abolition of the ports of Rochefort and Lorient as military ports: Lorient to be retained exclusively as a port for new constructions, and Rochefort to be gradually reduced, but retained for a certain period as a port for building small craft. The economy that would be effected is considerable, and as it is said that these ports are now very little used as commissioning ports, the abolition of the Prefet Maritime and a large staff seems reasonable. This reform is in accordance with the often-expressed desire for specialization of the military ports, each in the particular rôle for which it is best adapted, and retaining only two of the five ports (Brest and Toulon) as commissioning ports.

However, the Chamber of Commerce at Rochefort is up in arms, and has held a meeting protesting against the proposal. And M. Thomson, late Minister of Marine, was also not in favor of it. He stated his views before the Commission, and was in favor of certain reductions and economies, but said that Lorient, which receives 7,000 men in the scheme of mobilization, must be retained as a commissioning port, and Rochefort is already specialized as a port for construction of submarines and destroyers, and must be retained as such, not for a period, but indefinitely; it is also important to retain Rochefort as a port of refuge and a revictualing port for the flotillas in the Gulf of Gascony.

La Situation Navale, by M. Rousseau, 29th May, 1908 (Letter No. V).—A modern navy is not only composed of fighting battleships for offensive purposes, but must also include surprise vessels specially designed for defensive work and the defense of the coast line. Defensive vessels are torpedo boats and submarines. Twenty years ago the former had engines capable of driving them at a speed of 20 knots, the speed of the battleship at this date being about 12 knots. The proportion between the speeds of the surprise ship and the vessel to be surprised was thus represented by five to three, which does not appear excessive, and should, therefore, be maintained. The *Dreadnought* now has a speed of 22 knots; therefore the

corresponding speed of the surprise vessel should be 37 knots. As was stated in the preceding article, England last year laid down a torpedo vessel of 1,800 tons and 36 knots speed; this vessel, the *Swift,* is, therefore, the torpedo vessel of the *Dreadnought* era. I called the *Swift* a luxury *(vaisseau de luxe);* she will, in fact cost more than 6,000,000 francs, and when chasing a *Dreadnought* at full speed she will burn six or seven tons more coal per hour than the latter when steaming 22 knots. The cost of the *Swift* is equal to the cost of thirty 20-knot torpedo boats of the type of twenty years ago. It has often been said that these small craft are ruination, and yet there are French Ministers of Marine ready to affirm in the tribune that the torpedo boat is the arm of the navy that has a moderate Budget.

Torpedo boats and submarines are the outcome of an idea long prevalent in France, that some day or other a small craft will be designed that will be more formidable than a heavy battleship. It is quite evident that when this day arrives the construction of these latter will cease, for no one would be so foolish as to build a large ship expressly to become the prey of a torpedo boat; but large battleships are still being built in every direction, which proves that the microbe destructor has not yet been discovered.

Ideas as to the value of defensive vessels have varied greatly, and the want of continuity in the construction of these vessels proves this; it has been the same in England as in other countries. In 1902 the British Admiralty made the following proud declaration before the Colonial Conference: "The word defense is designedly omitted because the first object of the British Fleet is not to defend anything, but to attack the fleet of the enemy, and by its destruction assure the protection of our possessions, of our mercantile marine and of British commerce. It would be a mistake to use the word defense, for it carries with it the idea of something to defend, and would turn attention to local defenses instead of fixing it on the force whose attack must be made impossible. The traditional rôle of the English Navy is not to act on the defensive."

Nevertheless, it was the British Navy which first constructed the torpedo boat, though defensive ideas did not always prevail, and in 1895, after building a hundred of these boats, they were discontinued; a short time previous to this, however, the building of destroyers of 260 to 300 tons had been commenced, and this policy has since been continued, increasing the size of the vessels from time to time; then the construction of coastal torpedo boats was again taken up in 1900, dropped in 1903, and taken up again in 1905 and 1906, destroyers of 800 tons and 33 knots speed being built at the same time, crowned with the *Swift* of 1,800 tons and 36 knots.

The price of such a vessel is out of all proportion to the services it can render; but to be quite impartial, we must add that it has been stated that the *Swift* has not only been designed to act as a torpedo vessel, but also as a fast dispatch boat, able to carry secret orders from one fleet to another when there is reason to suppose that wireless messages may be tampered with, her great speed making her safe against any attempt at capture.

England is also organizing an important flotilla of submarines, the first of which date from 1900. There are already about 60 submarines in commission or under construction, but the enthusiasm for them appears on the wane, as all those approved by Parliament have not yet been commenced. The defensive fleet of England now includes 170 destroyers, 59 torpedo boats and 50 submarines.

The arm of the defensive Navy is the torpedo, which, if effective, can deliver a terrible blow, the explosion of the gun-cotton charge being sufficient to demolish the bottom of the strongest-built ship. The fresh effort being made by England to develop the defensive part of her Navy coincides with the proposal that has of late been made in the manufacture and perfecting of the torpedo. The latest patterns have an effective range of 4,000 meters, and the "Obry" apparatus, by giving them a straight trajectory, increases their accuracy, while the heating of the air which works the engines has increased their speed. But no matter how admirable this arm may be, its action is by no means certain; firing a torpedo is a delicate

operation, involving much care, and, if it is necessary, to make corrections for wind for a projectile from a gun, how much more difficult is it to ensure a straight course in a torpedo passing through the medium of water, and liable to the effects of currents and tides?

Everyone has remarked the pretty wave made by a steamer when under way, which seamen call the "moustache." It appears that the moustache has great effect on an approaching torpedo, deflecting it to such an angle that when striking a vessel the firing pistol may not act. It is also easy to put an obstacle in the path of a torpedo. The English retain the torpedo net, and believe in its efficiency, while towards the close of the siege of Port Arthur a number of torpedoes were stopped by a floating boom. The *Sevastopol* battleship at this time, when lying outside in the roadstead for safety from the Japanese siege guns, had a boom erection placed round her, and night after night the Japanese torpedo boats attacked her and fired their torpedoes without success. Finally, her captain himself sunk his ship to prevent her falling into the enemy's hands.

It is said that the most satisfactory way of employing the torpedo is to use it at the end of a battle to complete the destruction of crippled ships; but it is worth considering whether, after the battle of Tsu-shima, it would not have been more to the interest of the Japanese if they had abstained from torpedoing ships which would assuredly have fallen into their hands.

The Germans, according to their modified 1906 program, intend building twelve torpedo vessels per year. From 1898 to 1906 the number built was six only. They long ago gave up constructing coastal torpedo boats, of which they possess 47, the last of this class being launched in 1897-98; they now only build sea-going vessels, whose displacement, at first 300 tons, increased to 400 in 1899, and later on to 420, 470, 485 and 487 tons, with a speed of 28 knots; the torpedo vessels of the modified program are from 525 to 670 tons, and have a speed of 30 knots. According to the estimates, Germany will in ten years have a flotilla of 120 torpedo vessels of more than

500 tons displacement. What does Germany intend doing with all these torpedo vessels? Some say that this crowd of small craft is intended to serve as a screen to her heavy fleet, to conceal its movements and prevent its being forced into action before the right moment. Seeing that the great German arsenal in the North Sea is at the apex of the angle formed by the coast of Jutland, running north and south, and the German coast running east and west, its blockade would be comparatively easy, and we can therefore understand that Germany may intend, by means of this large flotilla, to give her fleet room to turn and a breathing space to her principal naval base.

Japan has 58 destroyers, about 20 torpedo boats and a few submarines bought in America.

The United States appear only to have a moderate trust in defensive vessels, and possess about 30 destroyers, 20 torpedo boats and 10 submarines; this is all the coast-defense vessels possessed by the Power that has the second largest fleet of battleships in the world.

In France we have many torpedo boats, but with the exception of our destroyers it may be said they are none of them really efficient, because even the last built are not fit for the duty now required in view of the increased speed of the battleship. When the *Dreadnought* was making a speed of 22 knots on her trials, we had torpedo boats going through their trials whose extreme speed was 26 knots, whereas, as has been already stated, the speed now required is 37 knots. The reason for this is to be found in the conviction of the officials at the Palais-Bourbon, that the small vessel is superior to the large. The great principle formulated by Admiral Aube regarding torpedo vessels is, invisibility, divisibility and number; from this it has come to pass that small torpedo vessels have been built to obtain invisibility, to increase their number, and because they are less costly; their number gave a false idea of their value, and coincided with the policy that the navy is made for the ports and not the ports for the navy. Also, with many torpedo vessels it is possible to favor many private building yards, and satisfy certain municipalities and certain deputies,

whose influence is measured by the number of million francs that the Government is induced to accord to their fellow-townsmen.

When he was at the Ministry of Marine, M. Pelletan (who had retarded the construction of submarines) ordered in ten months, from November, 1903, to August, 1904, 72 torpedo boats of 90 to 100 tons and 26 knots, at a cost of more than thirty million francs (£1,200,000). At this time no other Navy was building torpedo boats of less than 200 tons.

Our destroyers of the type in commission have a displacement of 330 tons, and a minimum speed of 28 knots, and are excellent little vessels as far as they go, but their speed is not sufficient. We now have destroyers of 450 tons under construction, though the English have raised the tonnage of theirs to 900 tons, and the Germans to 670 tons.

France uncontestedly possesses the largest number of submarines; including those building we have exactly one hundred, but we have lost the *Gymnote,* the *Lutin* is not repairable, *Q 61* has been turned into an oil cistern, and the construction of the two *Guépes* has been countermanded; the building of others, such as the *Omega,* the *Y* and the *Z* has also been checked, so that if we deduct those that are not completed we have about 60 submarines or submersibles fit for service of a great variety of types. *Q 61* was to have had a very small tonnage; the *Guépes* displaced 45 tons; the *Naïde* class 70 tons; we oscillated for some time between 180 and 200, and now our submersibles have attained 600 tons.

The rival merits of submarines and submersibles have been much discussed with us. It may be said that the submarine is like a fish that carries its floating power inside, while the submersible carries it outside; or, in other words, the water tanks that have to be filled when a dive is intended are inside the hull for the first, and outside for the second. The struggle that has been going on between the two types has had a most retarding effect, and it is to the credit of M. Thomson that it is now concluded. His policy is to lay down each year a cer-

tain number of a well-proved type, continuing at the same time trials with newer types.

Our submarine flotillas are distributed more or less all round the coast; the two most important are those of Dunkerque and Cherbourg. There is no flotilla at Brest, but Rochefort has one berthed in the port of La Palice. There are also flotillas at Toulon, Bizerta and Saïgon, and it has been proposed to station one at Madagascar.

As far as defensive vessels are concerned, each of the five chief navies of the world has had to consider its own particular circumstances; but it must be noted that the American Navy, which has progressed most rapidly of recent years, has been the least concerned in providing a defense for its coasts. On the other hand, our own Navy, which has fallen to the fourth place, is the one which has expended most on coast-defense vessels. If the six battleships of the *Danton* class, or others, had been commenced in 1904 with the 30,000,000 francs (£1,200,000) devoted to out-of-date torpedo vessels, our coast defenses would not be any worse off than they are now, and Lord Brassey would not have to ask in his Naval Annual for 1907 whether our decadence as a naval Power may not become still more pronounced.—"Le Temps."

The Naval Situation, by M. Rousseau (Letter No. 7).—In this study of the naval situation we have endeavored to describe the evolution of the modern fleet and its causes. The disappearance at the beginning of the eighteenth century of the navies of Spain and Holland left surviving those of England and France, which for nearly a century held the undisputed supremacy of the sea. Of these two navies, one, that of France, has dropped out of the race, and has given place to younger navies; the other, that of England, has made during the last decade of the last century and the first of the present a most admirable advance; but, allowing herself to be surprised by the rapidity of this evolution and hypnotized by the Navy of her nearest neighbor (for notwithstanding all, England is haunted by the fear of invasion), she failed to foresee the con-

sequences of the Russo-Japanese war or those brought about by the invention of the *Dreadnought.*

The complete victory of Japan has ruined the prestige of the European in Asia, and has, so to speak, created an England in the Far East against the England in Europe, and when the British Admiralty constructed the *Dreadnought,* though her plans were kept a secret, Parliament was nevertheless informed that it was intended to reduce the number of naval bases abroad, which was a sufficient indication of the nature of the new vessel.

Now that the naval supremacy of England is no longer absolute, the ambitions of other countries are being excited. In the few past years the United States have constructed a fleet which is at present the second most powerful fleet (though before very long it will be surpassed by Germany), and which is now engaged in advertising its power by a cruise round the world. It has been said that the American people are slow of speech but strike hard; certainly in this case they are not conspicuous by their silence, and one might even call them talkative did not the word "bluff" occur in the American language. They understand better than anyone how to give a special significance to this cruise round the world. The Australian Prime Minister asked that Admiral Evans' squadron might visit the Australian ports, and this request, if not suggested, was at once agreed to with enthusiasm. The English Government now solicits a visit from this same squadron, and the reply is that to visit England would delay the program, though the Australian visit meant a detour of 4,000 to 5,000 miles, while the visit to England would take them little more than half that distance out of their way. Is it not evident from this that the American Government thinks more of establishing cordial relations with the Colony than with the mother country? The Colony, being situated in that American lake, the Pacific Ocean, and the ties between it and the mother country being only those of a respectful daughter arrived at her majority.

And while England is suffering this little annoyance from

one young Navy, another young Navy is avowedly endeavoring to take her place. Germany for twenty years past has been fighting her with energy in the commercial field, and gaining ground every day. From a military point of view it is Germany that is carying out Lord Cawdor's program of laying down four new battleships every year, while England is not building more than three per year.

In whatever direction we turn we notice how much the diminution of British power reduces the chances of peace. In the Pacific, where, according to Lord Esher, England has abandoned her supremacy, a conflict of interests has arisen between the United States and Japan, which perhaps is not yet altogether smoothed away. In commercial matters the struggle is becoming keener and the competition more bitter, and the mercantile flag of England is disappearing from these waters to the great prejudice of English shipowners and merchants.

In the Indian Ocean English commerce is also being attacked and the northern frontiers of England's most important possession are not secure, while signs of revolt are becoming apparent throughout all India.

In the Atlantic Ocean the situation for the moment is not disturbed, but on one of the dependent seas England finds herself face to face with a Power which is becoming stronger day by day, and each day more menacing. Everywhere the elements of conflict appear to exist. Can we expect that everywhere the solution will be a pacific one? We must unfortunately be prepared for the worst, for interests clash too much for us to hope that these matters will be peacefully arranged. Where will this war cloud burst? Who can say? It may safely be said, however, that when it does, we cannot remain indifferent to it. By our alliances, our *entente,* our treaties, we are everywhere in contact with the interested parties, and we cannot preserve our independence or our liberty of action unless we are strong enough to make them respected; in the same way we cannot benefit by our alliances unless we bring to our allies advantages comparable with those which we expect from them. We are situated between the adversaries, and we

must not allow our territories to become the field of battle, and to effect this we must be strong. Many people think that we need not go to war unless we like, but this is absurd, and it is impossible to avoid being drawn into the conflict in certain circumstances. We in France have been far too long ready to accord every virtue to defensive tactics, which entail all the risks of losing without any of the chances of winning, and have buried millions in matériel which may be now looked on as so much bankrupt stock—bankrupt because such was our blindness that it has not been kept up to date or followed the progress made by our rivals. It is today no longer able to fulfill its object, and three or four years hence will only be fit for the scrap heap.

In all seriousness our Navy, in which everything has been sacrificed to the defensive, only exists at all by favor of the few offensive vessels which the too rare prudence and enlightenment of some of our former Ministers of Marine has endowed it, by doing which they have deserved well of the country; but of vessels of real offensive power we do not possess sufficient to make up a squadron equal to half the fleet of Admiral Evans. We have six battleships building, but they do not fill the deficiency either as regards the United States or Germany; we must have others with the least possible delay.

Let us not forget that France has the largest national Budget of the whole world, and that this Budget, which is the guarantee of our liberty, of our social institutions, of the protection of our citizens, may excite the covetousness of others. It is only a madman that leaves the key in the door of his strong-room, thereby inviting robbery, and mad is the people that exposes its riches to the public gaze without taking the necessary precautions for protection.—"Le Temps."

Trials of Submarines.—The new submarine *Emeraude,* a vessel of 390 tons, designed by M. Maugas, has recently carried out a very successful long-sea run. Leaving Cherbourg at 5 P. M. on the afternoon of the 2d ultimo, she maintained for over eighty hours a steady speed of 9 knots, her

petrol motors working perfectly without the least hitch. The distance to be run was 693 miles, but on account of foggy weather the commander had to keep well out to sea, so this distance was consequently somewhat increased. The crew stood the trial, and the discomforts to which they were necessarily exposed, very well.

Later in the month the three new submersible *Pluviose, Ventose* and *Germinal,* also undertook a successful long-sea run, the distances covered being 750 miles at a speed of 9.5 knots. At the conclusion of the run on their return to Cherbourg each vessel had about 3,000 liters of naphtha still remaining, which would have allowed them to continue the run up to 900 miles without replenishing their store of oil.

The new submarine *Rubis* has been undergoing her trials at at Cherbourg, which have already been twice interrupted by a breakdown. When her port screw was making 329 revolutions, and the starboard 327, the contract number of revolutions being 325, a defect showed itself in the port piston, and the trial was again brought to a premature conclusion.

A serious accident, resulting in the foundering of the new submersible *Fresnel,* occurred when that vessel was entering the port of La Palice at La Rochelle, where the submarine station to which she has been allotted is fixed. She left Rochefort on the morning of the 24th ult., and made the passage in fine weather, arriving at the entrance of the harbor at 6 P. M.; as she was rounding the south jetty something went wrong with her steering gear and she came into collision with it, sustaining such injuries that she sank immediately. Most of her crew, which consisted of 2 officers, 22 men, and some workmen from the dockyard at Rochefort, were fortunately on deck at the time, and were all rescued by a small steamer, which, running between La Palice and Re'Island, happened to be on the spot at the time. The *Fresnel* sank in six fathoms, and the work of refloating her will be at once taken in hand. She is a vessel of 398 tons of the *Laubœuf* type, of which there are several in the service, 154 feet long, with a beam of 15 feet,

and a draught of 9 feet 9 inches; she is provided with a steam motor for surface running, and electric for plunging.—"Le Vie Maritime" and "Le Temps."

GERMAN NAVAL NOTES.

*The State of Battleship Construction at the Time of the Launch of the First German Battleship of 18,000 Tons, Ersatz Baiern, March 7th, 1908.**—There was published not long ago in "Schiffbau," the leading German naval technical periodical, a summary of the battleships under construction at the time of the launch of the first German 18,000-ton ship. Although the summary contains nothing which cannot be found in different naval publications, yet the matter contained has been brought together in the article in question in a convenient form, and it has been thought, therefore, that it may be of interest to reproduce it, especially as there are some interesting comparisons drawn between German battleships and those of other countries:

"On March 7th the battleship *Nassau* (Ersatz *Baiern*) was launched from the Imperial Dockyard at Wilhelmshaven. She is the first of the new era of giant battleships carrying a powerful battery of guns of heavy caliber, that England, by the construction of the *Dreadnought,* has imposed on all nations which ought or which wish to have a powerful fleet. The *Dreadnought* belongs to the English naval program of 1905-06, and was commenced at Portsmouth on October 2d, 1905, at a time when no State thought of laying down battleships of over 18,000 tons, carrying ten 12-inch guns. It is true that the Japanese battleship *Satsuma,* which is slightly larger, was commenced on May 15th, 1905, at Yokosuka, but she only carries four 12-inch guns, with twelve 10-inch; she was launched on November 15th, 1906, commenced her trials in November, 1907, and is now completed. The *Dreadnought* was launched on February 10th, 1906, and commissioned on

*Translated from the "Revue Maritime."

March 28th, 1907. We cannot fix exactly the date of the commencement of the Ersatz *Baiern* and of the ship of the same type, the Ersatz *Sachsen,* which is to be launched next (launched July 1st last), exact information on this point not having been published; but these ships belong to the program of 1906-07, and were commenced some time in July, 1907. The month when the keels were laid down was only made known last month. Nevertheless, the Ersatz *Baiern* was constructed, relatively speaking, rapidly up to the time of her launching.

After the appearance of the *Dreadnought* several States set themselves to construct or to project ships as large and carrying as heavy an armament; but England alone has received orders from abroad for such battleships, three having been ordered for the Brazilian Government.* It has been reported that these ships will be purchased either by the United States or England; but, in any case, they are, according to the contract, to be ready for sea during 1909. At this date England will have ready three other ships of this class, the *Bellerophon, Temeraire* and *Superb,* all three launched in 1907, and the three somewhat smaller so-called armored cruisers, *Indomitable, Invincible* and *Inflexible,* which carry eight 12-inch guns, giving her seven, and quite possibly ten of these new powerful ships, while Germany will have two, the Ersatz *Baiern* and Ersatz *Sachsen,* ready for sea.†

France, under her 1906-07 program, is constructing six large 18,000-ton battleships, the *Danton, Mirabeau, Vergniaud, Condorcet, Diderot* and *Voltaire,* but their construction has been delayed. The slip at Brest, on which the *Danton* has been laid down, was not ready until the beginning of 1908; the *Mirabeau,* at Lorient, had to wait to be laid down until after the launch of the *Waldeck-Rousseau,* at the beginning of March, 1908. These two ships, constructed in the Govern-

*The first of the three, the *Minas Geraes*, was launched from the Elswick Yard on the 10th September last.—TRANS.

†Another ship of the same type, the *Rheinland*, was launched on 26th September last.—TRANS.

ment Dockyards, are to be completed in 1910. The four others are being built in private yards, and are to be delivered in April, 1911. In 1909 none of these ships will be ready for sea.

In the United States, according to the program of 1906-07, two large ships of 20,321 tons, the *North Dakota* and *Delaware*, are being constructed, the keels of which were laid down in October and November, 1907, respectively. On April 1st, 1908, the *Delaware* had been advanced 12.6 per cent. in her construction, and the *North Dakota* 21.4 per cent.* These ships will carry ten 12-inch guns, and will probably be completed in 1910.

Russia has commenced at the Baltic Yard, on the slip left vacant by the launch of the *Imperator Pavel I*, on September 7th, 1907, the construction of a battleship of 20,000 tons.

Nothing is known with any certainty of the new battleships under construction for Japan in the Imperial Dockyards at Yokosuka and Kuri. Little as other countries have succeeded in surrounding their new ships in a veil of secrecy, Japan has at least done so with remarkable success. Outside certain circles in England interested in their construction, scarcely anything precise has been allowed to leak out about these ships.

Italy, again, has made at Castellamare all the preparations for laying down a ship of 19,000 tons.

With the exception of England and Brazil, Germany is in advance of all other countries in the construction of her large ships.

But this agreeable reflection is considerably lessened by the fact that our ten next strongest battleships of the *Deutschland* and *Braunschweig* classes are only of 13,200-tons displacement, and only carry four 11-inch with fourteen 6.7-inch Q.F. guns.

The 11-inch guns, like the 7.6-inch, are 40 calibers long, and even the *Schlesien* and *Schleswig-Holstein*, the latest of the class, only carry this armament, which seems very light compared to that of foreign ships. Thus of the ten last English battleships constructed before the *Dreadnought*, the eight

* The *North Dakota* has since been launched on 10th November, 1908.—TRANS.

of the *King Edward VII* class carry four 40-caliber 12-inch guns and four 46.6-caliber 9.2-inch guns, while the two last ones, the *Agamemnon* and *Lord Nelson,* carry four 45-caliber 12-inch and six 46.6-caliber 9.2-inch guns. The superiority of these ships, then, from the point of view of armament, is a matter of great importance, for it is due to the lessons of the battle of Tsushima that so much importance is attached to superiority in guns of heavy caliber; the *Agamemnon, Lord Nelson,* and, above all, the *Dreadnought,* are the result of these considerations.

The new Japanese battleships, the *Satsuma,* already mentioned, and the *Aki,* a similar ship, launched at Kure on April 15th, 1907, of 19,000 tons and 19,800 tons, respectively, carry four 45-caliber 12-inch guns and twelve 48.6-caliber 10-inch.

The Vickers-Maxim 45-caliber 10-inch guns have a muzzle energy of 28,225 feet, with a rate of fire of three rounds a minute; the Elswick 50-caliber 10-inch guns have a muzzle energy of 33,315 feet, with a rate of fire of two rounds a minute. It is these guns we have to concern ourselves about. The German Krupp 40-caliber 11-inch guns fire one round a minute, and have a muzzle energy of 33,561 feet. Thus the Japanese 10-inch guns, manufactured at Elswick, are alone two times superior to the 11-inch guns of the German ships, without counting in the 12-inch guns.

Of the fifteen United States battleships which precede the *Delaware* and *North Dakota,* the five of the *Georgia* type of 16,300 tons carry four 40-caliber 12-inch and eight 45-caliber 8-inch guns. The superiority of the gun armament of these ships over that of the German vessels is unquestionable. They were all launched in 1904. The six ships of the *Connecticut* type which followed them have a displacement of 17,000 tons, and carry as their armament four 45-caliber 12-inch guns and the same number and type of 8-inch guns, as also have the *Mississippi* and *Idaho,* two ships of only 14,700 tons. Next come the *North Carolina* and *Michigan,* with a displacement of 17,900 tons, which have not yet been launched, but which on January 1st had been advanced 33.8 and 37.9 per cent., respectively;

their armament is to consist of eight 12-inch guns, but whether of 40 or 45-caliber length is not yet settled.

The four recently completed French battleships of the *Démocratie* type of 14,870 tons displacement carry four 40-caliber 12-inch guns and ten 50-caliber 7.6-inch; they may fairly be considered superior in gunpower to the ten most recent German battleships, as well as are the two earlier ships of the same displacement, the *Patrie* and *République,* which carry eighteen 40-caliber 6.4-inch guns as their secondary armament, even admitting that the Krupp matériel is superior to that turned out at the Ruelle Factory.

The six latest Italian battleships are equally superior from the point of view of their armament to the German ships; of these six ships, the *Roma* was launched on April 16th, 1907, but is not yet ready for sea. The *Benedetto-Brin* and the *Regina-Margherita,* of 13,430 tons, carry four 12-inch and four 8-inch guns, all of 40 calibers; the four others carry two 12-inch and twelve 8-inch guns. All the guns were manufactured at the Armstrong Works at Pozzioli.

Since England considered it necessary to envelop the construction of the *Dreadnought,* the *Invincible,* etc., in a veil of secrecy, other countries have more or less adopted this new policy.

All the new English and French battleships are to be furnished with turbines; on the other hand, the three Brazilian ships will have engines of the old reciprocating type. The turbines of the three English ships of the *Bellerophon* type are to develop 23,000 I.H.P.; those of the *Superb* have been constructed by the Wallsend Company; the others by Vickers, at Barrow; the *Superb* and *Bellerophon* are fitted with Babcock-Wilcox water-tube boilers, the *Temeraire* with Yarrow. These ships have a displacement of 18,600 tons, are 490 feet long, a beam of 82 feet, with a draught of 27 feet. The armament is similar to that of the *Dreadnought,* viz., ten 45-caliber 12-inch guns, but they carry twenty 4-inch guns as anti-torpedo weapons in place of the twenty-seven 12-pounders of the *Dreadnought.* The belt armor is 11 inches, tapering to 6, as also are

the redoubt and conning tower, the barbettes being 12 inch. The ships have two tripod masts, but this method of construction may well soon disappear, as a projectile is more likely to knock away one of the three legs than one simple mast, which can be made very slight, as it has not to carry any heavy weights. If one of the three legs were shot away, the other two, with all they may be carrying, would also go. The *Agamemnon* and the *Lord Nelson* also have tripod masts; but if these have been supplied to several ships it is in order that the *Dreadnought* may not appear to be the only one so fitted, which would show to the whole world the faultiness of this installation.

In regard to the three ships of the *St. Vincent* class, the displacement has been raised to 19,250 tons, with a length of 500 feet, a beam of 84 feet, and a draught of 27 feet, the I.H.P. of their turbine engines has been raised to 24,500, giving a speed of 21 knots. Their armament is the same as in the others of the type, but the 12-inch guns will be 50 calibers in length instead of 45.

The trials of the three ships of the *Invincible* class (a fourth is to be built) have been awaited with much interest. These ships have a displacement of 17,250 tons, are 530 feet in length, with a beam of 78 feet 6 inches, and a draught of 26 feet. Their Parsons' turbine engines, which work four screw shafts with four screws, or to develop 41,000 I.H.P. and give a speed of 25 knots,* their water-tube boilers being of the Babcock-Wilcox type. Their armor belt, which extends the whole length of the ship, is 7 inches in thickness, tapering to 4 inches, and they are fitted with two rudders.

The three Brazilian battleships are reported to have a displacement of 19,250 tons, to be 510 feet long, with a beam of 85 feet and a draught of 25 feet; the engines to develop 26,000 I.H.P., giving a speed of from 20 to 21 knots. The armament, it is said in some quarters, will consist of ten 13.5-inch guns, all supplied by the Elswick firm, the heaviest guns yet

* This speed has been exceeded in the trials since carried out by two knots.—TRANS.

carried by modern ships. The five turrets are on the keel line, the three center ones being higher than the two others, which will allow the whole ten to fire on the broadside, with a bow and stern fire of four. The coal supply will be 2,000 tons.

The two United States battleships are to have a displacement of 20,000 tons, with a length of 510 feet, a beam of 85 feet 3 inches, and a draught of 27 feet. Their reciprocating engines are to develop 25,000 I.H.P., giving a speed of 21 knots. The armament is to consist of ten 12-inch and fourteen 5-inch guns, the axes of the 12-inch guns being from 22 to 33 feet above the water line. Protection being afforded by a water-line belt 8 feet wide and 11 inches thick, with an upper belt 7 feet 3 inches wide and 10 inches thick, the secondary battery being protected by 5-inch armor and the turrets by 11-inch. The coal supply is calculated at 2,500 tons.

As we have already said, not much is known about the new Japanese battleships, but, according to the program, four of 19,500 tons, with engines developing 26,000 I.H.P., giving a speed of 20 knots, are to be constructed, with four 18,500-ton armored cruisers, with a speed of 25 knots. It is not, however, probable that the two ships which are following the *Satsuma* and *Aki* are included in these four. It is also known that during the next seven years two other battleships are to be built to take the place of older ships. It seems to be generally admitted, however, that the new ships are to carry a powerful battery of medium guns, in addition to numerous 4.7-inch for use against torpedo boats, which, in spite of their war experiences, the Japanese do not seem inclined to give up, thus placing themselves in opposition to almost all the other Powers.

The Italian battleship *A*, building at Castellamare, is to be a ship of 19,000 tons displacement, 500 feet long, 68 feet 8 inches beam, and to have turbine engines developing 30,000 I.H.P., to give a speed of 22.5 knots, and will cost 50,000,000 lire (£1,979,166).

The six new battleships which, as we have already stated, the French are constructing, will be vessels of 18,320 tons, 505 feet long, a beam of 83 feet 6 inches, with a draught of 27

feet 6 inches. Their turbine engines are to develop 22,500 I.H.P., to give a speed of 19 knots; they will have eight screws with a diameter of 8 feet 8 inches, arranged on four shafts. The armament is to consist of four 50-caliber 12-inch guns, of a new model, twelve 50-caliber 9.4-inch guns, sixteen 12-pounders and eight 3-pounder guns, and two submerged tubes for 23-inch torpedoes of a new type. Another group of six ships of 21,000 tons displacement are further to be laid down, but it is as yet uncertain whether they will be commenced in 1909 or 1910.

With regard to the new German battleships now under construction, very few details have been allowed by the Admiralty to leak out, but according to the semi-official "Marine Rundschau" they are vessels with a displacement of 18,000 tons. Three other ships of the same type, the Ersatz *Oldenburg*, Ersatz *Siegfried* and Ersatz *Beowulf*, as well as the first-class armored cruiser *G*, which, like *E* and *F*, already building, will have the armament of a battleship, are to be laid down this year (1908). The armored cruiser *E*, which is under construction at the Imperial Dockyard, Kiel (launched April 11th, and named the *Blücher*), has a displacement of 15,000 tons; *F*, which is being built by Blohm & Voss, of Hamburg, is to be fitted with Parsons turbines, and as she is to cost 36,000,000 marks (£1,800,000), should be a very large and powerful vessel. It is a question if we are wise in following the example of the English in concealing the characteristics and armaments of our new ships. Foreign navies interested in them possess all the details, and one may well ask, therefore, if any real purpose is served by withholding the information from the public. It is only thanks to the interest shown in naval matters by the public that the Minister of Marine has been provided with the means necessary for realizing his program.

Towards the end, then, of 1910 we shall have ready four of these ships, and we can employ as first-class ships the ten battleships of the *Deutschland* and *Braunschweig* classes. The ten ships of the *Kaiser* and *Wittelsbach* types, with their four 9.4-inch guns and fourteen 5.9-inch, are hardly worthy of the

name. France will have in 1910 the six ships of the *Danton* class, the equals of our four new ships, with the six of the *République* class, and the *Suffren* and *Bouvet,* all equal, if not superior, to our ten German ships. She will also have, in addition, seven other useful ships carrying 40-caliber 12-inch and 40-caliber 10.8-inch guns. England will have eight *Dreadnoughts,* three *Inflexibles* and eight of the *King Edward VII* class, with the *Lord Nelson* and *Agamemnon,* all equal to our four ships, and she can also dispose of some thirty ships which in England are considered superior to our most recently completed ten battleships. And to these forty-eight vessels might be added, under certain circumstances, the three Brazilian ships. Japan, in 1910, will be able to dispose of four battleships equal to our four, as well as two superior to the ten of our own fleet already mentioned, viz., the *Katori* and *Kashima,* ships of 16,500 tons, carrying four 12-inch and four 10-inch guns, besides twelve 6-inch; and further of another six, equal to our ten, and not taking into account the *Poltava, Peresviet* and *Pobieda,* captured from the Russians. The United States in 1910 will have four battleships equal to our four, thirteen inferior to them, but which in any case are superior to our *Deutschlands* and *Braunschweigs,* and eight others at least their equal. Italy will have one ship of the same class as our four, two equal to our ten, and four a little inferior to those ships; while Russia may possibly have in her Baltic Fleet three ships equal to our four and two slightly inferior to our ten.

Thus England will dispose of 47 first-class battleships, Germany of 14, France of 14, Japan of 12, Italy of 7, Russia of 5, and the United States of 25. It must also be noted that in 1910, while the German Navy will only dispose of 10 armored cruisers, England will dispose of 35, France of 19 (counting the oldest, the *Polthuan,* built in 1895), the United States 13 (including the *Brooklyn,* of 1895, and the *New York,* 1891), Japan 14, of which four carry a modern battleship's armament of four 45-caliber 12-inch and twelve 6-inch guns. In view of these figures, it is scarcely a question yet of Germany exceed-

ing the United States or France in battleships, while to equal or exceed England is not to be spoken of."—"Journal Royal United Service Institution."

THE HOPKINSON FLASHLIGHT ENGINE INDICATOR.

Among the principal improvements effected in the construction of the modern engine indicator the reduction of the weight of the reciprocating parts, including the pencil motion, is one of the most important, inasmuch as it is now possible to use the ordinary type of instrument for indicating high-speed steam engines, as well as for gas and oil-engine work, where the changes in pressure are both sudden and severe. Notwithstanding this, however, there are still circumstances under which the inertia of the moving mechanism has a prejudicial effect upon the accuracy of the diagram, and as a consequence inventors have cast about for some method of eliminating, or at least enormously reducing, this influence. One method, probably suggested by the Thomson reflecting galvanometer, is to use a beam of light reflected from a mirror, which latter receives a movement proportional to the pressure of the working fluid. Forms of these optical indicators have been introduced in which the piston and spring of the pencil indicator have been replaced by a thin diaphragm of steel, the movement of which is communicated through a short lever to the pivoted mirror, which thus records the pressure acting on the diaphragm. At the same time the mirror is given a motion about another axis, at right angles to the first, corresponding to the piston motion. These diaphragm indicators have exceedingly small inertia, and can be used on engines of very high speed.

The Hopkinson indicator is a recently introduced optical instrument of the piston and spring type, combining the small inertia of the diaphragm instrument with many advantages which can only be secured by the use of a piston. Of these, one of the most important is that the spring can be placed outside and can be kept cool; whereas a diaphragm (which is

spring and piston in one) is necessarily in contact with the hot gases, and subject to considerable variations of temperature. Moreover, it is claimed that by the use of pistons of different area, and by grinding the springs to the right stiffness, any desired sensibility can be given to the instrument.

A general view of the instrument is given in Fig. 1. The

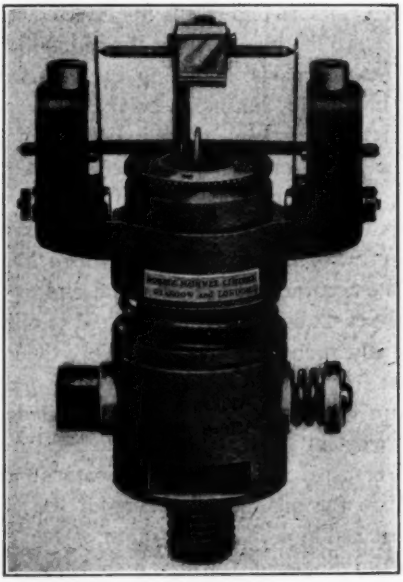


Fig. 1.—HOPKINSON FLASHLIGHT INDICATOR.

lower portion or body contains the cylinder and piston, the cock and a nipple-screwed ¾-inch Whitworth, for attaching to the cylinder or other fitting. The upper part of the body is turned to receive the double-horned frame or bracket shown, which is held up in contact with the cylinder cover by a spiral spring. In the upper face of the bracket and the lower face of the ring under the spring are ball races, this arrangement allowing the bracket to be freely rotated around the cylinder. The spring consists of a strip of steel, resting in grooves in the two horns

of the frame, and held by the two cheese-headed screws seen in the upper part of the illustration. The mirror is clamped to a steel spindle, the ends of which are pivoted in small holes in the two spring supports shown. Connection is made between the cross spring and the mirror by a vertical spring seen behind the mirror. This spring, while sufficiently rigid to transmit the motion of the main spring without buckling, is flexible enough to allow for the resulting slight angular motion. The mirror is thus turned about the axis of the spindle by an amount which is proportional to the displacement of the main spring, and therefore to the pressure under the piston.

In order to give the other motion to the mirror, the frame is positively connected by a linkage to a reciprocating part of the engine, and is thus caused to rock as a whole about the axis

Fig. 2.—HOPKINSON FLASHLIGHT INDICATOR.

of the indicator body. The motion thus given to the frame must be in phase with and proportional to the piston motion, and a convenient form of reducing gear with provision for clamping to the frame is furnished by the makers. It should be added that three pistons are used, the areas being in the ratio of 1, 2 and 4. Two springs are provided which are ground so that their stiffnesses are in the ratio of 1 to 5. A wide range of sensibility is thus obtained. The smaller pistons fit inside liners which are inserted in the bore of the indicator body.

For making the diagram visible a simple and neat form of

photograph camera of light weight is made, which is clamped on to the indicator in the manner shown in Fig. 2. A concave mirror is used in this case, which forms an image of the source of light upon a ground-glass screen. The screen may of course be replaced by a photographic plate, and a record of the diagram thus obtained. A very small and brilliant point of light is obtained by the use of an electric-lamp filament placed behind and at right angles to a fine slit.

For workshop and drawing-office use the camera will generally be found most serviceable, as only with this is it possible to obtain permanent records of the diagrams.

For purposes in which no permanent record of the diagram is desired, but in which it is only wished to read off the pressure

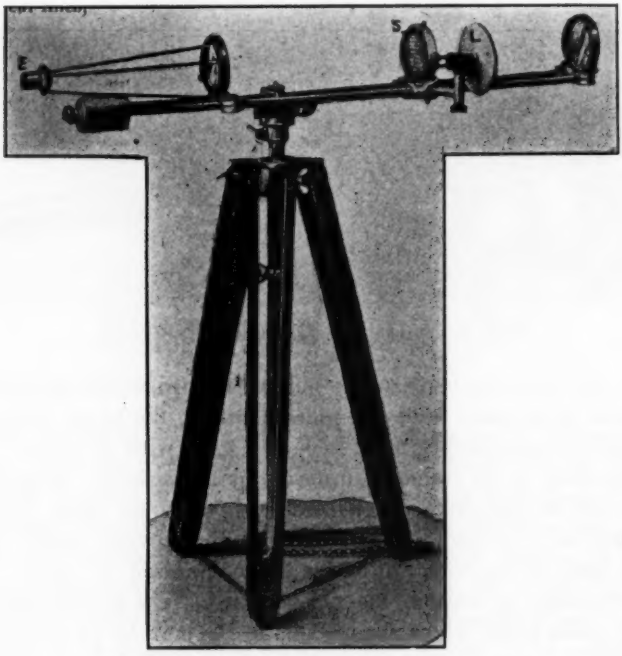


Fig. 3.—HOPKINSON FLASHLIGHT INDICATOR.

at some particular point in the stroke, or to observe the general shape of the diagram, the method of observation is by means of the telescope shown in Fig. 3.

The source of light is the filament of a 4-volt lamp L, placed behind and at right angles to a narrow slit. The rays from this, after reflection from the plane mirror of the indicator, fall upon the convex lens, which is placed about 18 inches from the mirror and is 4 inches in diameter. Ultimately the spot of light is received on the graduated screen S, which is engraved with horizontal and vertical lines, and on which the diagram is projected as a bright line easily visible in broad daylight. This method of observing the diagram is more particularly useful when it is desired to read off the pressure at some particular point (as, for example, the compression or suction pressure in a gas engine), or to note the effect on the diagram of some change in the conditions. It can also be usefully employed for valve setting, having manifest advantages over the present practice of taking a large number of pencil diagrams, each of which is glanced at and thrown away. The telescope is made chiefly of aluminum, and is mounted on an adjustable wooden tripod. It should obviously be of great advantage for demonstration purposes in technical laboratories and for research work.—"Mechanical World."

REMOVAL OF OIL AND GREASE FROM BOILER FEED WATER.

By Nathan E. Krause.

Among the many problems with which steam users, managers of power plants, ice manufacturers and others have to contend, and have always been attempting to solve, that of completely removing the oil or grease from condensation water has probably been the most baffling and difficult, particularly that portion of it which is in the finely emulsified state indicated by the cloudy or milky appearance of the water.

This emulsion is caused by the churning of the mixture of condensed steam and lubricating oil in the steam engine or steam-pump cylinder. It passes out with the exhaust and is

found in the hot-well water resulting from the condensation of the steam. Attempts to remove the oil sufficiently to make a safe boiler water by means of separators in the exhaust line have been successful only at so much expense, uncertainty and vigilance that many stations reject the water from surface condensers and purchase city water at enormous costs.

Coarser particles or drops of oil which have not been emulsified or gone into the milky condition can be readily removed by either skimming tanks or coarse filtration through hay, excelsior, turkish toweling, terry cloth, etc. It will be found, however, that no matter how fine the filtering material has been, the milky appearance of the water caused by the oil has not appreciably changed, showing that considerable quantities of oil are still retained and leaving it unfit for ice making, boiler feeding or other purposes where a clear and pure water is the most important consideration. As long as this cloudy appearance remains the water will be unsafe for boiler feed and will sooner or later be sure to result in serious trouble.

It may also be mentioned that by the use of coagulants and chemicals involving reactions of various kinds the oil and milky appearance of such water may be removed, but any chemical treatment which necessarily leaves in solution many substances deleterious for ice manufacturing or boiler purposes cannot be recommended nor trusted by careful engineers, owing chiefly to the well-known harmful effects of chemicals upon the valves, boiler plates and brass fittings.

In consequence of this, oily condensation water in large quantities in power plants, ice plants and other industrial establishments is now run to waste, which, if the oil were completely removed, would be ideal water for boiler feeding, ice making and many other purposes, and which, if saved, would result in considerable economy, particularly in cities where water rates are high, and on shipboard, where special evaporators must be used to obtain pure water.

In seeking some suitable substance that would clear this condensation water completely, and without chemical treatment with its attendant evils, the writer has discovered among the magnesian products of serpentine quarries a peculiar fibrous

sand which is practically insoluble, and, by reason of its extraordinary physical property of attracting and retaining the oily matter in condensation water, is eminently fitted and suited to remove the last traces of oil from the latter. Its strong physical property of attracting greasy matter may be judged by the fact that the material will retain or absorb from 50 to 100 per cent. of its own weight of emulsified oil from the water after the coarser oil particles have been removed.

That this method of purifying or freeing water from oil or grease is a purely physical and not a chemical one is shown by the fact that by suitable solvents the oil can be readily removed from the spent fibrous magnesian filtering material, and the oil so obtained may be used over again for lubricating, etc.

The process, which is patented, and which is now being introduced, requires no more care than an ordinary sand filter, needs no expert attendance and is continuous in operation, the only special requirements being a pressure pump of the requisite capacity.

An additional advantage of this process is that by passing through the serpentine fiber or material the effects of the free sulphuric and other acids found in certain streams and brooks throughout the coal regions become neutralized and the water rendered entirely safe and serviceable for boiler use.

I have also discovered that this serpentine waste or fibrous serpentine sand has the property of removing the coloring matter and peaty substances contained in many well and other waters when these are filtered through or otherwise brought in contact with the before-mentioned material.

The apparatus for this process is manufactured by Alexander Miller & Bro., Jersey City, N. J.—"Power and The Engineer."

OIL-FUEL RESULTS.

Except in the case of steamers built for carrying oil in bulk, or those trading to or from or in the region of the oil fields, it can scarcely be said that liquid fuel has made much headway in the merchant service. It is true that the evaporative

efficiency, weight for weight, is from 33 to 70 per cent. better than coal, according to the calorific value of the latter, and that the reduction in bunker capacity and in weight of fuel carried enables more cargo to be taken, or a smaller ship to be built for a given duty, or a higher speed to be realized for the load carried. In the case of the high-speed Cunarders, for instance, there might have been a possible reduction of between 2,000 and 3,000 tons in displacement, and this would have increased greatly the speed for the same power, or reduced the power for the same speed. But with oil in this country selling at 60s., as compared with anything from 10s. to 20s. per ton for coal, there is not much inducement to adopt the liquid-fuel system. Indeed, the great cost is carrying weight with economists, even at the Admiralty, notwithstanding the great strategical and tactical advantages of oil fuel already well known.

There are other gains, however, in the reduction of the cost of burning the fuel—in the loading, trimming and stoking of fuel, in the smaller staff required and in the repairs, etc., bill. It has been difficult to get exact comparative data of the financial results of burning oil and coal, apart from the calorific results. In the accompanying table there are given such comparative figures from three merchant ships in service:

COMPARISON OF THE LABOR COST PER DAY OF BURNING COAL AND OIL IN THREE STEAMERS.

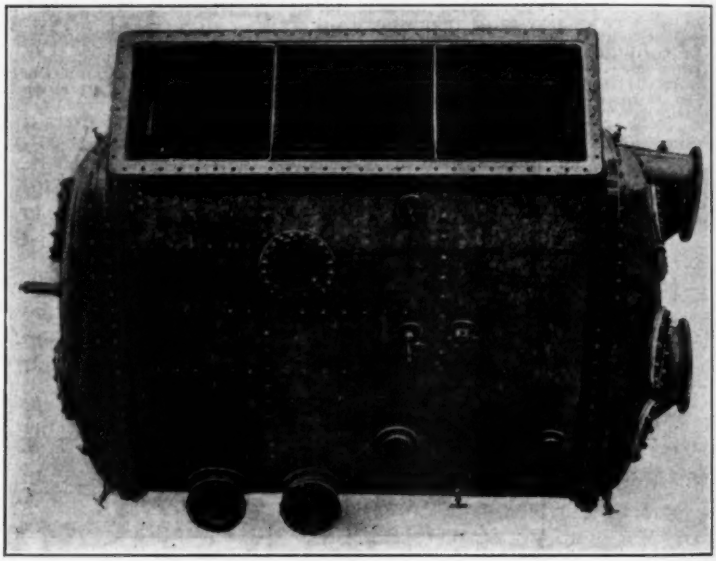
Example.	Fuel.	Boiler draught.	Tons of fuel used.	Number of firemen.	Wages of stoke-hold complement.	Victuall-firemen, etc.	Repairs and maintenance.	Total cost.	Total cost per ton of fuel.
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
					£ s. d.	£ s. d.	£ s. d.	£ s. d.	s. d.
1	Coal	Nat'ral	22½	11	1 9 4	0 11 0	0 5 5	2 5 9	2 0
	Oil	Do.	15	3	0 8 0	0 3 0	0 0 9	0 11 9	0 9½
2	Coal	Forced	29½	14	1 17 4	0 14 0	0 10 1	3 1 5	2 1
	Oil	Do.	19½	3	0 8 0	0 3 0	0 1 0	0 12 0	0 7½
3	Coal	Forced	300	...	19 12 0	12 13 0	5 5 0	37 10 0	2 6
	Oil	Do.	200	12	2 0 0	0 18 0	0 7 6	5 5 6	0 4

There is given a comparison of the expenses in three different ships, the third a moderate-sized cargo carrier. Column 4 gives the consumption, respectively, in each ship for the same service, and it will be seen that the oil is about 33 per cent. less than the coal; in other words, two tons of oil give the same energy at the propeller as three tons of coal. The number of firemen (Column 5) and the wages paid (Column 6) in the smaller steamers when using oil fuel is less than one-fourth what they are when using coal; but with increased size of ship and greater power of machinery the gain is augmented. Thus the owner of the cargo steamer using oil pays in wages only one-fifth of the sum disbursed when burning coal. Oil does not need to be trimmed nor conveyed by men from distant bunkers. For very small cost in steam-pumping power it is automatically fed into the boiler, which is not the case with coal. The relative repair and maintenance costs given in Column 8 are most significant; liquid fuel is a preservative of steel; as the boiler doors are never opened, as with coal burning; there are no such sudden variations in temperature as those which affect junctions of tubes with tube plates and involve other troubles with coal-fired boilers. The net result is that oil in a steamer using 200 tons per day costs 4d. per ton to burn, against 2s. 6d. for coal. This does not include the first cost of the fuel or plant for separating water from the oil, heating, compressing and air-spraying the oil.—"Engineering."

MARINE TYPE UNIFLUX CONDENSER.

In our issue of December 18th we referred to the great interest at present being taken in the design of marine surface condensers, and we expressed an opinion that preventing air getting into a condenser would prove a better investment than complicated methods of taking it out. The general trend of our article was that simplicity should be observed in any new design of engine-room plant. It is, therefore, with considerable interest that we give our readers the results of recent

trials on a turbine-driven torpedo boat of H. M. Navy, fitted with the marine type of G. & J. Weir's uniflux condenser shown in our illustration. It is a matter, perhaps, for some surprise that such results are possible from an apparatus which apparently only differs from existing designs in its general contour, and in which the flooding of the lower tubes would appear to be exaggerated. The special contour is claimed to give not only a good steam distribution over the tubes, but



MARINE UNIFLUX CONDENSER.

also to maintain the flow of steam at approximately uniform velocity. G. & J. Weir, Limited, have proceeded on the lines that the transmission of heat is largely dependent on the rate of flow of the steam over the tube surface, and in the proportions of their design this point is carefully embodied, the contour being utilized to a large extent to secure the requisite velocity, variable tube spacing being also a factor.

Arising from the shape of the condenser a novel method of

construction for such condensers has been developed. This method consists in the use of flanged steady plates carried up to the steam inlet, which extends the entire length of the condenser. By flanging these plates the entire atmospheric load on the flat sides and top is taken, and deformation is prevented without the use of any stays whatever, thereby avoiding any chances of leakage at the stay ends—a common defect in condensers of special shape.

The trial results of the plant referred to are as follows:

Approximate total steam condensed at full power, pounds	78,000
Total tube-cooling surface, square feet	2,730
Circulating-water branches, diameter, inches	14
Sea temperature during trial, degrees F	48.5
Approximate condensation rate per square foot of surface, pounds	28.5
Guaranteed vacuum at above sea temperature (at 30-in. barom.)	28.325
Actual vacuum obtained at trial (at 30-in. barom.)	28.6

It should also be noted that nothing in the nature of baffle plates is used in the design of the condenser, nor is it divided in any other way than in a vertical direction by the tube steady plates. On the vessel in question there was the usual large number of auxiliary connections to the condenser, and consequent opportunities for leakage, such as exist in a war vessel of the type named. The high degree of vacuum recorded is accordingly very satisfactory.—"The Engineer."

SHOOTING IN THE NAVY.

The three Blue Books, entitled, respectively, "Result of Test of Gunlayers with Heavy Guns," "Result of Test of Gunlayers with Light Q.-F. Guns" and "Result of Battle Practice with Torpedo-boat Destroyers," for the year 1907. In each of these there is again to be noticed a decided improvement in the shooting of all arms.

Following the method which we employed last year in dealing with these books, we will take the heavy guns first. In 1908, 117 ships fired in the trials and 1,277 were employed, these figures comparing with 121 and 1,365, respectively, in 1907. The results obtained in these two years are as set out in the accompanying table:

	1907.	1908.
Number of hits	4,073	4,826
Number of misses	5,455	4,183
Total rounds	9,538	9,009
Percentage of hits to rounds fired	42.70	53·57

A new size of target was used in these operations in 1907 for the first time, and, consequently, it is rather difficult to compare the present year with those prior to 1907. We may say, however, that the 1907 target was considerably smaller than that used prior to that date.

In 1907 the percentage of hits to rounds fired worked out to 79.13 on the earlier and larger target, and 42.70 on the 1907 target. The 53.57 per cent. of hits obtained last year on the smaller target would probably represent over 90 per cent. of hits on the earlier and larger target, and is a figure which is, in any case, nearly 25½ per cent. better than that reached in 1907, though that year was a great deal better than those which had gone before. There is good ground, therefore, for the satisfaction with which the Lords of the Admiralty note "further improvement in the results as compared with those obtained in 1907, when the shooting showed an advance over previous years." As a matter of fact, with the exception of the year 1904, when there was a falling off of something over 3 per cent.—which was much more than counterbalanced by an improvement of nearly 14 per cent. in 1905—there has been an increase year by year in the efficiency of the shooting with big guns in the Navy ever since the year 1899, and of recent years this increase has assumed greater and greater proportions.

An advance has also taken place in the number of hits per gun per minute, as is shown in the following table, which

compares the results of 1907 and 1908 on the smaller target brought into use in the former year:

	Hits per gun per minute.	
	1907.	1908.
12-inch and 10-inch	0.40	0.56
9.2-inch	2.01	2.20
7.5-inch	1.58	2.51
6-inch Q.-F. and B.-L.	3.32	3.98
4.7-inch and 4-inch Q.-F.	2.38	3.32

It will be observed that with every size of gun there has been an improvement. In fact, the year 1908 showed better all-round shooting with guns down to 4-inch than had been achieved in any of the ten preceding years.

The same tale may be told regarding the results of the tests with light quick-firing guns. This will be appreciated from the following table, which sets out the details of the figures for the years 1905, 1906, 1907 and 1908:

	1905.	1906.	1907.	1908.
Number of ships that fired	86	89	122	111
Number of guns	1,118	1,421	1,898	1,384
Number of hits	2,228	4,666	7,462	6,120
Number of misses	8,291	8,845	10,272	6,823
Percentage of hits to rounds fired	21.63	34.53	42.08	47.28
Hits per gun per minute:—				
12-pounders	2.12	3.417	4.471	5.319
6 and 3-pounders (except Vickers)	1.97	3.358	3.640	4.507
3-pounders, Vickers	——	8.144	6.140	6.059

It will be observed in the above table that very nearly every other shot found the target, and that in 1908 the percentage of hits to rounds fired was nearly two and a quarter times as large as it was in 1905, only four years ago.

A still greater improvement is recorded as a result of battle practice from torpedo-boat destroyers. The comparison of the above table with that which follows is all the more inter-

esting in that, to a large extent, the sizes of the guns used were the same; in fact, the advantage is with the torpedo boats, as the smallest gun used in the tests with them was the 6-pounder. The following table gives the figures for the four years 1905, 1906, 1907 and 1908:

	1905.	1906.	1907.	1908.
Number of ships that fired.....	57	52	121	139
Number of guns.....	342	312	669	701
Number of hits.....	653	1,004	2,069	4,066
Number of misses.....	2,608	1,898	3,709	2,906
Percentage of hits to rounds fired	20.02	34.60	35.81	58.32
Hits per gun per minute:—				
12-pounder, 12 cwt.....	1.54	2.43	3.97	7.44
12-pounder, 8 cwt.....	——	——	——	5.41
6-pounder	1.98	3.73	3.57	7.12

There are several points worthy of attention in this table. The first is the large increase in the percentage of hits to rounds fired. The year 1907 showed but a small improvement on the year 1906, but in 1908 the percentage of hits to rounds fired reached the remarkable figure of 58.32 per cent., as compared with 35.81 in 1907. Another significant fact is the increase in the number of hits per gun per minute both with the 12-pounder 12-cwt. guns and with the 6-pounders.

We are unable, owing to lack of space, to go more deeply into the mass of figures given in these three Blue Books, but a study of them will well repay the trouble it involves, as the results achieved by each vessel are given in detail.—"The Engineer."

"MONEL METAL"—RECENT PROGRESS.

A Natural Alloy of Nickel and Copper.

By H. E. Flewellin.

Of alloys there is no end, for, according to our necessities we create a metal to suit them and without denying to each alloy special and valuable properties, let us say that one which has met with popular approval, which shows a great range of adaptability and whose field of usefulness is being rapidly

enlarged is "Monel Metal," a natural alloy of nickel and copper; composed approximately of 70 per cent. nickel, 1½ per cent. iron and the balance copper. In smelting and refining the ore from which "Monel Metal" is made the nickel and copper are not extracted or separated, and, therefore, appear in the finished alloy in the same relative proportions. As a result we have a metal that is tough, strong, as non-corrosive as pure nickel, the same in appearance, and whereas nickel as a pure metal is relatively expensive owing to the difficulty of isolating it, the treatment of this ore consists merely in eliminating the impurities, excepting a small percentage of reduced iron; this is done at a cost which permits favorable competition with bronzes, German silver, etc.

The properties of "Monel Metal," however, are of such high order that they should not be confused or compared with the numerous white metals of German or nickel-silver, which are the results of varying percentages of nickel, copper, zinc, lead, tin, etc. In all these alloys nickel is the important factor and usually the combination is employed for color, hardness, resistance to certain chemical action, etc., though the manufacture and treatment of such alloys is too well known to call for special comment. The purpose of this article is to present briefly in systematic form the properties and applications of "Monel Metal" which have been investigated and recorded.

"Monel Metal" has practically the same specific gravity as copper and melts at (1,360 degrees cent.) 2,480 degrees Fahrenheit. It is ideally suited for any castings which are subjected to severe strain and shock, and which yet must be of a metal that will not corrode. Propeller wheels may be made of "Monel Metal," in one piece instead of casting the blades and hubs separately and bolting them together. These wheels are made from metal having the following physical properties:

ILLUSTRATION.

Wheels for S. S. *Creole*.....	Tensile strength, pounds per square inch...77,500
Diameter, 9 feet 6 inches...	Elastic limit, pounds per square inch 36,000
Weight, 6,500 pounds.....	Elongation in 2 inches, per cent.....28.0
	Reduction of area, per cent.....29.50

This emphasizes the possibility of reducing weight and still obtaining a metal stronger and stiffer than now generally used. As further applications in castings, I may cite rudders, desk fittings, center boards, water ends of pumps, valves, plumbing fixtures, pickling apparatus, jig plates, harness mountings, etc.

"Monel Metal" is readily rolled into plates and sheets, and as an important field for competition with copper may be mentioned roofing—here the high resistance to acids, weather conditions, etc., coupled with its low coefficient of expansion (.00001375 against copper .00001666) ductility and flexibility makes it extremely attractive. The new Pennsylvania Terminal in New York City, the largest in the world, is being roofed with this metal, which was adopted after exhaustive tests by the railroad engineers.

COMPARATIVE TESTS.

One-half-inch Plates—Standard Test Specimens.

	"Monel metal."	Soft steel.	Copper.
Tensile strength, pounds	90,000	60,000	34,000
Elastic limit, pounds	45,000	30,000	18,000
Elongation in 2 inches, per cent	30.0	35.0	52.0
Reduction of area, per cent	60.0	35.0	57.0

FURTHER APPLICATIONS OF HOT-ROLLED SHEETS.

Ship plates, sheathing, roofing, gutters, leaders, skylights, sash chains, ventilators, drip pans, mine screens, coal chutes, smokestacks, gaskets, cut nails, tacks, etc.

COLD-ROLLED SHEETS.

Cooking utensils, milk cans, candy molds, hospital equipment, coffins, watch cases, cigarette cases, jewelers' stock, desk fittings, knives, forks, spoons, coin blanks, reflectors.

PHYSICAL PROPERTIES OF CASTINGS.

	Grade "B."	Grade "C."	Grade "D."
Tensile strength, pounds	85,000	65,000	70,000
Elastic limit, pounds	40,000	25,000	30,000
Elongation in 2 inches, per cent	10.0	30.0	20.0
Reduction of area, per cent	14.0	35.0	25.0

BARS, RODS AND WIRE.

Shafts, piston rods, valve stems, bolts and nuts, horse bits, resistance wire, motor-cycle spokes, rustless screens, nails, screws, rivets, etc.

A prominent manufacturer of bolts and nuts has just completed 144 tests on "Monel Metal" bolts and steel bolts and says:

"If the bolt heads are well formed, the thickness of the head could be made 5-16 inch."

A. L. A. M. Standard thread is from 10 per cent. to 20 per cent. stronger than U. S. Standard thread.

Rolled thread is from 5 per cent. to 10 per cent. stronger than cut thread of the same size and style.

The "Monel Metal" bolts or studs elongate before breaking about the same as steel bolts of the same size.

"The A. L. A. M. thread in a steel bolt is the weakest point. It will strip every time. It is not so in the Monel bolt. This is a great advantage for the Monel bolt, because the bolt will stand tightening and loosening and still be strong enough. Half-inch Monel bolts are from 30 per cent. to 35 per cent. stronger than steel bolts of the same style and size. Three-eighths-inch Monel bolts are 60 per cent. stronger than steel bolts of the same style and size."

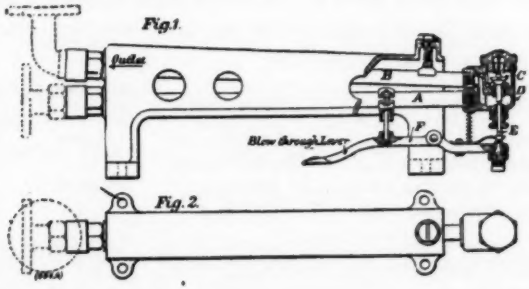
Hot rolled 1-inch bars.	"Monel metal."	Government specifications phos. bronze.	Government specifications Tobin bronze.
Tensile strength, pounds.....	108,750–110,000	40,000	60,000
Elastic limit, pounds.....	80,000–104,000	.....	30,000
Elongation in 2 inches, per ct...	27.0–13.5	15 to 30	30
Reduction of area, per cent.....	51.1–43.7	.....	.....

A careful perusal of the above-quoted figures will show at a glance the many different properties of this metal, and perhaps suggest to the reader many applications in which it might excel. This metal has been on the market but a short time, and up to date its field of usefulness has been continuously and steadily enlarging and there is every prospect that it will gain further favor as those connected with the metal industries become more generally and intimately acquainted with "Monel Metal."—"The Metal Industry."

ENGINEERING SPECIALTIES.

THE GEIPEL STEAM TRAP.

The main feature of the Geipel steam trap consists in the method by which the expansion is multiplied without the use of levers, cranks, etc., by which great simplicity is obtained, combined with a movement which is definite and which is not partly lost, as is usually the case where levers and pivots are adopted. Recently important improvements have been made in the construction of the trap, although in respect to the above features it remains unaltered. A practical demonstration of the construction and working of the new trap was given in London on Monday by Mr. Geipel. To distinguish the trap from its predecessor it has been given the title of the "Rapidity Steam Trap." The valve is arranged so that it is held on its seat by steam pressure instead of, by means of an abutment, against steam pressure as in the case of the ordinary trap, consequently the valve is held on its seat, without straining the expansion parts, with a much greater force, whilst the diameter of the valve has been increased.



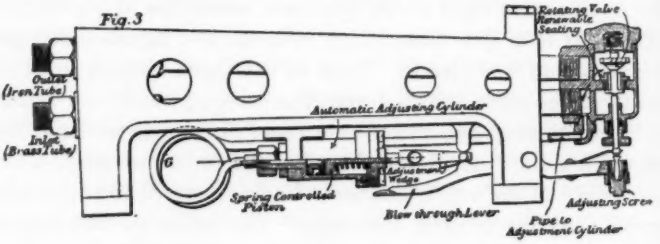
Construction of the Trap.—The construction of the trap is shown in Figs. 1 and 2. It will be seen that the brass tube A, which forms the inlet and is connected to the vessel to be drained, is at the bottom of the trap, and the iron tube B, which constitutes the outlet, is at the top as in the ordinary Geipel trap. In the valve body a passage leads from the en-

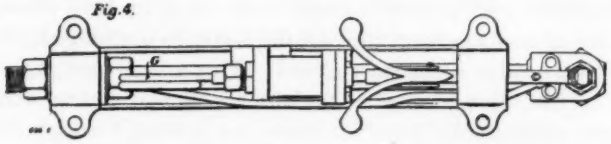
trance of the brass tube to the upper side of the valve C, whilst the passage from the lower side connects to the iron tube B; the pressure therefore comes on the top of the valve. When the trap is cold or full of water the brass tube A is contracted, so that the valve casing B is accordingly pulled into its lowest position; and the valve spindle E, which shuts against the lever F, is in contact with the valve and has raised it from its seat. When steam enters the brass tube the latter expands and moves the valve casing upwards. The steam pressure closes and holds the valve tight on its seat until water has again entered the brass tube and caused it to contract and again pulled the valve casing downwards. Just as the valve opens a rush of water takes place, which forces the valve upwards and causes a large opening, and therefore a rapid discharge, whilst at the same time the rush of water catches the veins provided on the periphery of the valve, and accordingly causes it to rotate and grind itself in at each discharge. The action of the trap is such as to dispense entirely with the objectionable throttling so commonly adopted with steam traps. A sharp blow through occurs at each opening until all the water is discharged, after which the valve is suddenly closed. This greatly prolongs the life of the valve because of the absence of that cutting action which occurs when water or steam are leaking through dribbling or improperly opened valves, or, in other words, passing through narrow apertures at high velocity. The lever for blowing through, which is shown in Fig. 1, is conveniently arranged so that it can be used by hand or by foot, according to the position in which the trap is placed.

THE ADMIRALTY TYPE.

Although the Rapidity trap works with considerably greater ranges of pressure than the ordinary Geipel, or any other type of expansion trap, yet for the purposes of the Admiralty, who specify that a trap must be capable of working from atmospheric pressure up to 300 pounds per square inch without adjustment, Mr. Geipel has introduced a new method of auto-

matic adjustment, which is illustrated in Figs. 3 and 4. This trap is known as the Admiralty type of Rapidity trap. The automatic adjustment is shown underneath the frame of the trap in Fig. 3. It consists of a cylinder which is connected to the pressure side of the valve casing by the coiled tube G. The position of the piston is controlled by a helical spring and moves the adjustment wedge outwards, according as the pressure rises, and *vice versa*. This has the effect of raising the abutment by means of which the valve is opened. It will



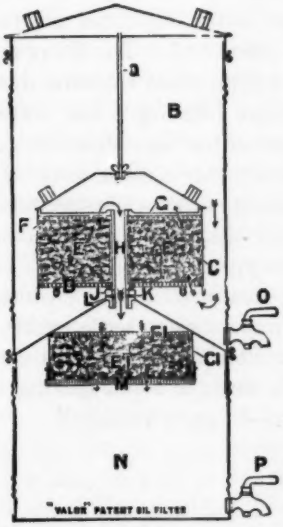


be observed that the higher the pressure at which the trap is to work, so the higher the position taken by the valve casing. The angularity of the wedge is adjusted so that it gives the precise movement required by the abutment to accommodate itself to the respective positions of the valve casing. I am informed that the Geipel trap is already fitted on over fifty vessels of the British Navy, as well as upon a similar number of vessels in the principal foreign navies.—"Page's Weekly."

THE AUTOMATIC FILTRATION OF WASTE OIL.

The effective cleansing of dirty oil from gas engines, dynamos and all kinds of machinery is becoming more generally recognized as an important factor in economic works manage-

ment. The accompanying illustration shows the method employed for this class of filtration in one of the best-known oil filters. The dirty oil is poured into the container at the top of the filter, and when it rises above the upper filtering chamber C, filtration commences. The oil penetrating upwards through the perforated plate D, cotton waste E, and plate G, overflowing into and down outlet tube H, on to and through upper perforated plate in the lower filtering chamber C1, cotton waste E1, and finally dripping into filtered-oil container,



DETAILS OF OIL FILTER.

can be drawn off thoroughly purified, ready for use at tap P. This filter, familiar to many of the readers of "Page's Weekly" as the "Valor," is made in six sizes for filtering approximately 2 to 50 gallons of oil per week. I am informed that the No. 5 filter, under test, filtered the dirty oil from two gas engines (11 B.H.P. and 16 B.H.P.) and also contents of 25 drip pans, collected from 185 feet of shafting running in 25 bearings at a speed of 220 revolutions per minute, for eight months before

it was necessary to recharge the filter with filtering material. A filter of this description effects a saving, of course, in many ways. Bv its aid one can use the best oil, filter the waste, and use again and again, at a cheaper rate than if one used the commonest oil obtainable. Again, as every plant user knows, nothing but the very best and purest oil should be used for any lubricating purpose. It is well known that common, improperly refined oil will scratch or circle bearings and shaftings and the delicate parts of expensive mechanism, causing slow but certain depreciation. It may pay even to filter new oil, as sometimes grit and other impurities are present, even in the most scrupulously refined oil. The filters referred to are automatic in action and continuous workers, thus avoiding settling either before or after filtering. The Valor Company, Ltd., who are the makers of the filter described, emphasize the fact that in order to thoroughly cleanse dirty oil it must be filtered slowly. Steam coils are fitted when specified, and are necessary for thick and heavy oils; they are especially useful when the oil contains a large proportion of water. Heating lubricating oil by means of a steam coil through which exhaust steam is passed will cause impurities to settle rapidly, inducing greater and more effective filtering capacity, but care should be taken, when live steam is used, to avoid stirring up sediment in the dirty-oil container.—"Page's Weekly."

SHIPS.

UNITED STATES.

The Launch of the Delaware.—The second American *Dreadnought* was launched from the yards of the Newport News Shipbuilding and Dry Dock Company on February 6. She was christened the *Delaware* by Miss Anne Pennewill Cahall, of Bridgeville, Del. The *Delaware* is a sister ship of the *North Dakota,* launched on November 10, 1908, in the yards of the Fore River Shipbuilding Company, Quincy, Mass. Each vessel has a displacement of 20,000 tons, and is designed for a speed of 21 knots. In the *Delaware* propulsion will be by means of two four-cylinder, triple-expansion, direct-acting reciprocating engines, designed for an indicated horsepower of 25,000, while in the *North Dakota,* Curtis turbines of the same total horsepower are being installed. Babcock & Wilcox water-tube boilers are used in both vessels.

The *Delaware* is 519 feet long over all, with a beam of 85 feet 2⅝ inches and a draught at a displacement of 20,000 tons of 26 feet 10 inches. Her armament consists of ten 12-inch breech-loading rifles, mounted in pairs in revolving turrets on the center line of the ship, in such a manner that all of the 12-inch guns can be fired on either broadside, four of them ahead and four of them astern. The secondary battery comprises fourteen 5-inch rapid-firing guns for repelling torpedo-boat attack. These guns are mounted partly amidships and partly at the bow and stern on the gun deck. There are also four 3-pounder rapid-firing guns, four 1-pounder semi-automatic guns, two 3-inch field pieces, two machine guns of .30 caliber, and two 21-inch submerged torpedo tubes.

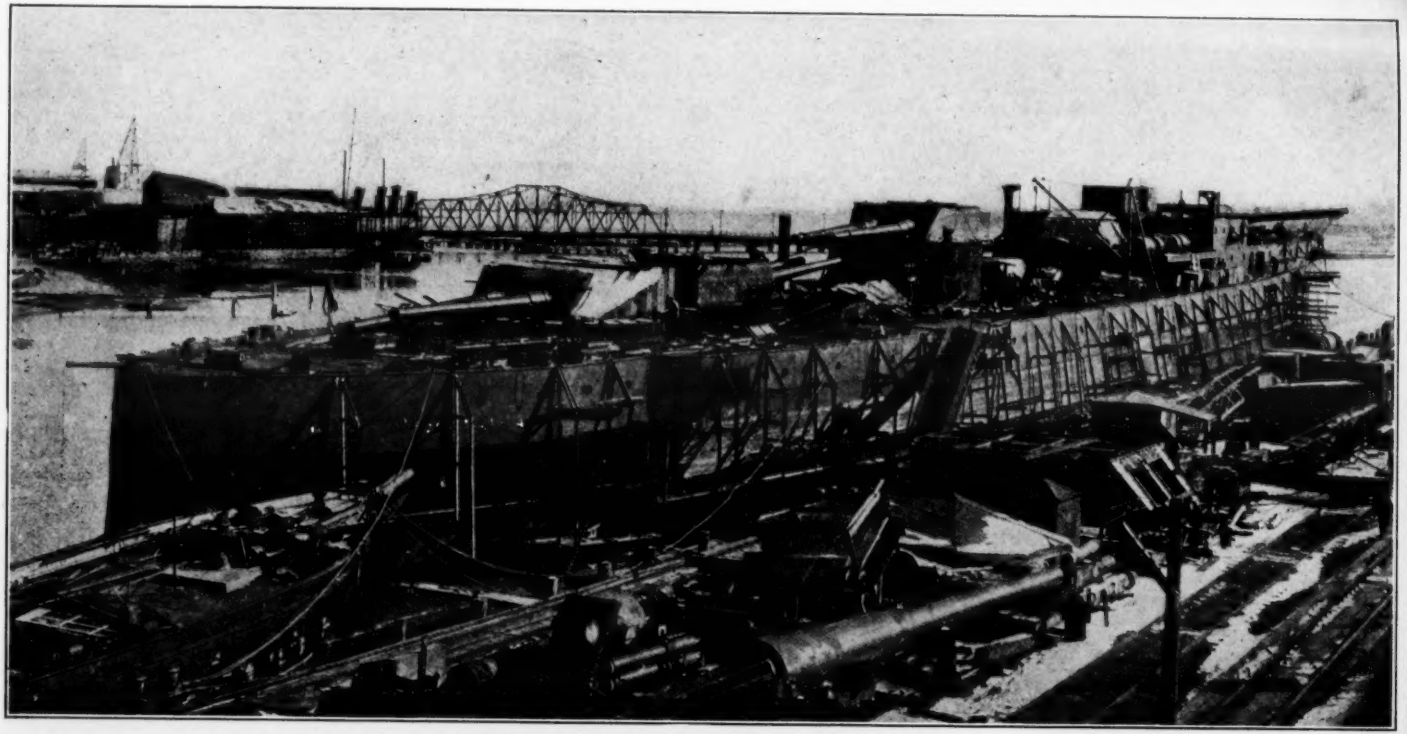
The ship is heavily armored, a water-line belt 8 feet wide extending the entire length of the ship. This belt is 11 inches thick amidships, tapering to 4 inches bow and stern. It extends

6 feet 9 inches below the full-load water line. The side armor is 10 inches thick, which is reduced to 5 inches at the main deck. The 12-inch turrets are protected by 12-inch and 8-inch armor.—"International Marine Engineering."

The Progress of the 20,000-ton North Dakota.—The accompanying photograph, taken at the yards of the Fore River Shipbuilding Company, shows the advanced stage to which the construction of our first battleship of the *Dreadnought* type, the *North Dakota,* has been carried. The point of view from off the starboard quarter has been well chosen, for it gives a striking impression of the unusual gun power of this great battleship. The total armament of ten 12-inch guns is mounted in five 2-gun turrets: two forward on the forecastle deck, the guns of the after turret firing above the roof of the forward turret, and three on the main deck abaft of the after mast. In our photograph the pair of 12-inch guns in the foremost turret are to be seen swung over to starboard. The other turret is to be seen in course of assembling upon the dock in the middle foreground. This view is instructive as showing the plate framing of the turret before the roof and the side and front armor have been put in place. In the immediate foreground is one of this turret's 45-caliber 12-inch guns. To the left of the breech of the gun lies one of the port shields, which are mounted upon the guns, within and close up to the port opening of the turret, for the purpose of preventing the entrance of shells. This shield moves with the gun as it is elevated or depressed, and serves to close the opening in whatever position the gun may happen to be.

Of the three turrets which show up so conspicuously on the after deck of the *North Dakota,* the first is elevated sufficiently to enable it to fire dead astern over the roofs of the two after turrets, so that if the *North Dakota* should be engaged in action with a ship or ships astern of her, she could concentrate the two guns in this turret and the two in the aftermost turret upon the enemy.

All five turrets are located on the longitudinal center line of the ship, and all ten guns can be fired on either broadside.



THE "NORTH DAKOTA" 80 PER CENT. COMPLETED.

This is one of the excellences of the *Dreadnought* design, and indeed the credit for introducing the center-line arrangement is due to our own naval constructors, with whom it originated. The arrangement affords a distinct advantage over the English system as used on the original *Dreadnought* and all subsequent ships of her type; for, although they also carry ten 12-inch guns, it is possible to concentrate on each broadside only eight of these guns. This limitation is due to the fact that two of the turrets are placed, one on each beam, with the superstructure of the ship intervening between them; and, consequently, on whichever side the ship is engaged, it necessarily follows that the broadside or "wing" turret of the opposite side is masked by the superstructure and cannot for the time being be brought into action. The English arrangement has the advantage that both of the wing turrets can be fired directly ahead or astern, which gives the ship a heavy end-on fire of six 12-inch guns, as against an end-fire of four 12-inch for the *North Dakota*. It is unlikely, however, that much fighting will be done from the end-on position. Future engagements will be broadside to broadside, and hence the American system assures a greater all-round efficiency for a given number of guns.

The series of triangular-headed vertical frames, which are seen hanging along the side of the *North Dakota*, are the supports for the platforms, from which the carpenters are engaged in bolting on the wooden backing for the side armor, a considerable portion of which, traceable on the photograph by its lighter shade, is already in place.

The *North Dakota* is a huge ship in every respect. Her length over all, 518 feet 9 inches, is equal to that of many ocean liners. Her beam of 85 feet 2½ inches is exceeded only by that of the *Lusitania* and *Mauretania*. Her normal displacement is 20,000 tons and her full load displacement over 22,000 tons. She will stow 2,500 tons of coal in her bunkers, and her Curtis turbines of 25,000 horsepower are designed to drive her at a contract speed of 21 knots, although on trial she will probably make over 22 knots. In addition to her main battery of ten 12-inch guns, she will carry fourteen 50-caliber

5-inch guns on the gun deck below. The protection will consist of a wide belt of armor, varying in thickness from 10 to 12 inches in the lower half of it, and from 10 to 8 inches in the upper half. As a protection against torpedo attack her hull is being built with an unusually complete system of underwater subdivision, which is so elaborate that no single blow from the torpedo could sink her.

In respect to the speed with which she has been built the *North Dakota* will mark an era in the progress of our Navy. Although her keel was laid as late as December 16th, 1907, she was launched November 10th, 1908, and at the present time is nearly 80 per cent. completed. She will probably have her trials during the late summer or early autumn, and, unless something unforeseen occurs, she will be completed several months before the contract date of June 21st, 1910.

GREAT BRITAIN.

British and German 1909 Warships.—Great secrecy is being maintained concerning the details of the two armored ships to be laid down for the British Navy in the current year. The following particulars have, however, been furnished by a reliable authority. The battleship, to be called the *Neptune,* will be laid down at Portsmouth, and will follow the same general lines as the *Dreadnought.* She will be 510 feet long, with a beam of 82 feet, and her normal displacement will be 20,250 tons. Her main armament will be the same as that of the *Dreadnought*—ten 12-inch guns—but she will probably have 4.7-inch weapons in the anti-torpedo battery. The disposition of the heavy guns will be the same as in the pioneer ship of the class; that is to say, three turrets will be on the center line, one forward and two aft, and one on either beam. The second center-line turret counting from aft will, however, be raised so as to fire over the aftermost, as in the *Michigan* and *South Carolina,* thus giving the ship an advantage of two guns over the *Dreadnought* in astern fire. The designed speed of the ship will be 21 knots, with turbines of 24,000

horsepower. Plans for a vastly improved battleship are in the possession of the British Admiralty, but will not be used until the ships of the 1909-10 estimates are commenced. The *Neptune* will complete a squadron of eight battleships of the same speed, armament and general design. She will be completed for sea in the spring of 1911.

The other armored vessel of the 1908-9 program is a cruiser, named the *Indefatigable,* which is to be built at Devonport. This ship will be a greater improvement on the *Indomitable* class than the *Neptune* will be over the *Dreadnought,* although the superiority will be largely a nominal one. The *Indefatigable* will be about 570 feet long, with a beam of 80 feet, and will displace normally 18,000 tons—700 tons less than the latest German armored cruiser. It will be remembered that all three ships of the *Indomitable* class, although designed for only 25 knots, greatly exceeded this on their trials. The new vessel has been designed for a speed of 28 knots, and if she exceeds the designed figure as much as the *Indomitable* did, she will exceed 30 knots—which is greater than the speed of most of our destroyers. Her horsepower, with Parsons turbines, will be 45,000, or 4,000 more than the horsepower of the *Indomitable.* Like the *Neptune,* she is to be completed early in 1911, by which time Great Britain will possess eight *Dreadnought* battleships of 21 knots and four all-big-gun cruisers of 28 knots.

The *Indefatigable* will carry the same armament as her predecessors, namely, eight 12-inch guns. In the *Indomitables,* however, it has been found very difficult to obtain a broadside of all eight guns, as was sought in the designs, and in the new ship the disposition of the armament will be so altered as to make this operation quite simple.

The German naval estimates for 1909, recently published, plainly indicate the energy with which that nation is pushing forward her naval development. During the coming year Germany will complete her first *Dreadnoughts*—the battleships *Nassau* and *Westfalen,* each of 17,760 tons and armed with twelve 11-inch and twelve 6.7-inch guns. In addition, the

armored cruiser *Blücher,* of 14,600 tons, and carrying twelve 8.2-inch and eight 5.8-inch guns, will be completed. The two battleships will join the high sea (or active battle) fleet, but the *Blücher* is destined to relieve the *Fürst Bismarck* on the China station. The 1909 estimates also include the last installments but one for the battleships *Rheinland* and *Posen,* each of 17,960 tons and carrying the same armament as the *Nassau* and *Westfalen;* and also for the armored cruiser *F,* not yet launched, of 18,700 tons and armed with twelve 11-inch and a number of smaller guns. The speed of all these battleships will be 19 knots, while that of the *Blücher* will be 23, and of the *F* 25 knots, the latter to be obtained with turbine engines of 45,000 horsepower, or 4,000 more than the designed horsepower of the British cruisers of the *Indomitable class.* Two small cruisers—the *Kolberg* and Ersatz *Jagd*—will be completed during the year, as well as a gunboat for river service in China and a division of twelve torpedo-boat destroyers. The cruisers are of 3,740 tons and 25.5 knots, having turbines of 18,000 horsepower, their armament consisting of ten 4.2-inch and a number of smaller guns. The destroyers are of 660 tons and 30 knots.

The other vessels upon which work is to be continued during 1909, and which will not be completed before 1911, are the three battleships to replace the *Beowulf, Siegfried* and *Oldenburg,* the armored cruiser *G,* two small cruisers to replace the *Schwalbe* and *Sperber,* a division of destroyers (twelve), and a number of submarines. Authentic details of these ships are lacking. During the year a commencement will be made with work on three new battleships, to replace the *Frithjof, Hildebrand* and *Heimdall,* the armored cruiser *H,* two small cruisers to replace the *Bussard* and *Falke,* twelve torpedo-boat destroyers, a tender for the torpedo experimental division, and several submarines, the latter to cost $2,500,000. Several of the large vessels in the fleet are to be taken in hand for thorough repair, and two floating docks are to be built, one with a lifting capacity of 40,000 tons, for the Imperial Dockyard at Kiel, and

one of 1,000 tons (for torpedo craft) for the Imperial Yard at Danzig.

The program of warship construction may be summarized as follows:

	To be completed.	To be continued.	To be commenced.
Battleships	2	5	3
Armored cruisers...	1	2	1
Small cruisers.....	2	2	2
Destroyers	12	12	12

—Percival A. Hislam, in "Scientific American."

The Propelling Engines of H. M. Cruiser Defence.—The dimensions of this cruiser, which was built at Pembroke Dockyard, are given in the Navy Estimates as follows:

Length, feet	490
Breadth, feet and inches	74–6
Mean load draught, feet	26
Weight of hull, including armor and backing, tons	8,215
Displacement on load draught, tons	14,600
Estimated horsepower (forced draft), I.H.P	27,000
Corresponding estimated speed, knots	23
Coal capacity at load draught, tons	1,000
Armament: four 9.2-inch breech-loading guns; ten 7.5-inch breech-loading guns; sixteen small quick-firing guns.	
Total estimated cost of ship, including guns, pounds	1,377,107

The *Defence* forms, along with H. M. S. *Minotaur* and H. M. S. *Shannon,* what is known as the *Minotaur* class of cruisers. The main engines for the *Defence* are of special interest, as, in all probability, they will be the last set of engines of the reciprocating type to be built for the British Admiralty, on account of the adoption of the steam turbine for naval vessels.

The propelling machinery is arranged in two separate watertight compartments, and consists of two sets of four-cylinder triple-expansion engines, balanced on the Yarrow-Schlick and Tweedy system. Each set has one high, one intermediate and two low-pressure cylinders, all fitted with liners and steam-jacketed. The diameters of the cylinders are respectively one of 40⅝ inches, one of 65½ inches and two of 74⅝ inches,

with a stroke of 48 inches. They are capable of developing collectively 27,000 I.H.P. at 125 revolutions per minute, with a steam pressure at the engines of 250 pounds per square inch. The cylinder covers and pistons are of cast steel and conical in form. Both sides of the pistons are machined, as is also the case with the inside of the covers and the cylinder ends.

Stephenson's link motion is adopted for working the valves, which consist of one piston valve for each high-pressure cylinder, two piston valves for each intermediate-pressure cylinder and one flat treble-ported slide valve for each low-pressure cylinder.

The starting platforms are arranged at the sides of the ship. All gear for starting and working the engines is led to convenient positions on these platforms.

Forged-steel columns support the cylinders at the front of the engines. The back columns are made of cast iron of the usual box section, and are formed to carry also the cross-head slipper guides, which have large bearing surfaces.

The crank shaft for each engine is in four pieces, each piece being forged from the solid. The journals and pins are bored hollow, and are 19⅞ inches and 22¼ inches in external diameter, respectively.

The engines are reversed by means of a double-cylinder steam engine, through worm-wheel and screw gearing, connected to a reversing shaft supported off the back columns and cylinders, and extending the whole length of the engines. Worm-wheel and screw gearing, driven by an electric motor, is supplied for turning the engines when overhauling.

Two condensers, of oval form, are fitted in each engine room. The total cooling surface of the four condensers is 32,400 square feet, and the total length of ⅝-inch brass tubing in the condensers to give this cooling surface is about 38¼ miles.

Contrary to the usual Admiralty practice, the exhaust steam from the engine passes through the condenser tubes, and is condensed by the circulating water passing over the outside of the tubes. Two centrifugal pumps in each engine room, made by Messrs. Matthew Paul & Co., supply the circulating water,

the pumps being so arranged that either can pump to either or both condensers in one engine room. The vacuum in the condensers is maintained by two sets of twin air pumps made by Messrs. G. & J. Weir, Limited. The hot water is also drawn off by these pumps and pumped, through gravitation filters made by Messrs. J. H. Carruthers & Co., into the feed tanks. One main and one auxiliary feed pump, by Messrs. Weir, are fitted in each boiler compartment. For making up lost water two evaporators, with distilling condensers, feed and brine pumps, etc., are fitted in each engine room. The whole of this plant has been made by Messrs. Weir.

Among other auxiliary machines, mention may be made of the refrigerating machinery, which includes one Haslam dry-air horizontal refrigerating machine, and one ammonia ice machine, the latter made by the Pulsometer Engineering Company.

There are four sets of steam-driven electric generators, made by Messrs. Belliss & Morcom, Limited, for supplying electric light and power throughout the ship, and four air compressors of the Brotherhood enclosed type for torpedo service.

There are two steering engines made by Messrs. Napier Bros., Limited.

Exclusive of the main-propelling engines, there are 56 steam engines and 40 electric motors supplied and fitted by the machinery contractors throughout the ship.

The boiler installation consists of 24 water-tube boilers of the Yarrow type, made by Messrs. Scotts, with a working pressure of 275 pounds per square inch. They are arranged in five water-tight compartments in the ship, with a central stokehold running athwartship in each compartment.

The steam collector of each boiler is 4 feet 2 inches in internal diameter and 11 feet long. The heating tubes are of solid-drawn steel, 1¾ inches in external diameter by about 8 feet long, expanded at each end and beaded in the thick tube plates of the steam and water drums. Each boiler has four external downcomer tubes of solid-drawn steel, 4 inches in internal

diameter, and there are three furnace doors to each boiler, with a common fire grate.

The boilers are designed for working with forced draft on the closed-stokehold principle, 32 fans being supplied for this purpose.

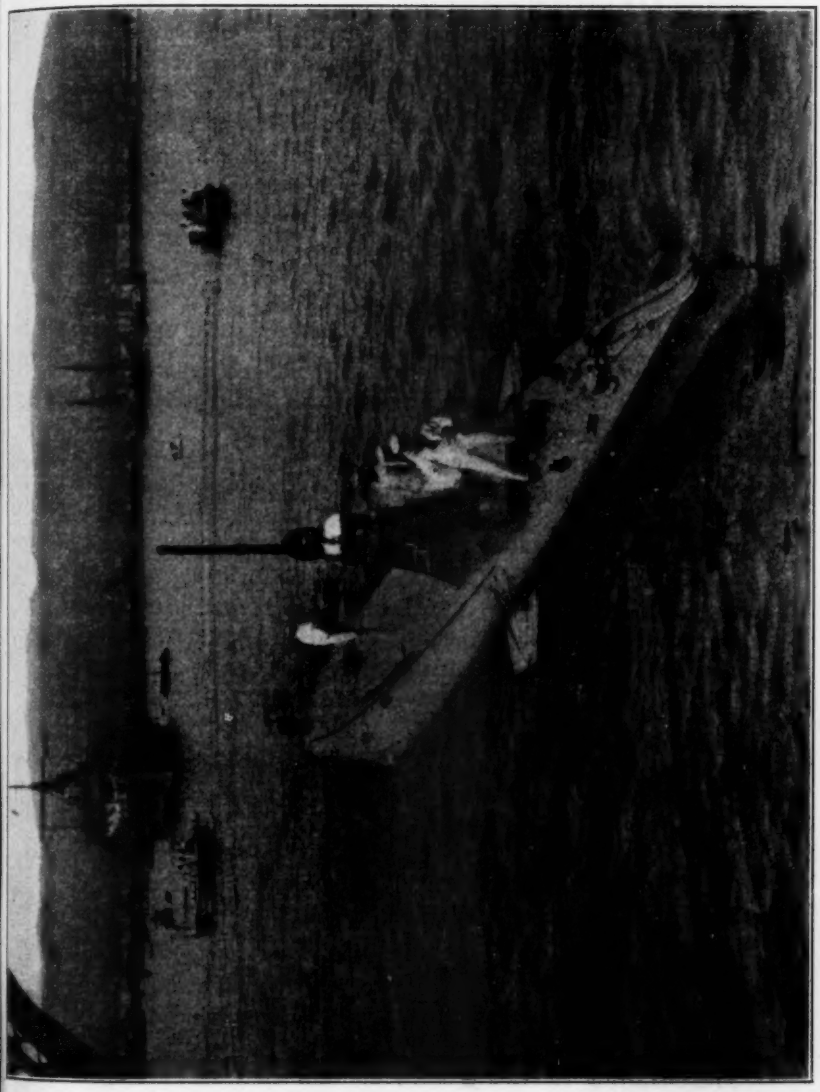
There are four oval funnels 11 feet 6 inches by 10 feet outside, rising to a height of about 70 feet above the fire grate.

A complete system of engine room, stokehold and revolution telegraphs, revolution tell-tales and indicators, automatic stoking indicators, navyphones and voice pipes are fitted throughout the ship for communication purposes.

The *Defence* completed her official steam trials on the 30th ult. On the full-power trial, of eight hours' duration, the mean revolutions per minute were 127, and the engines indicated 27,570 horsepower. As there was a haze in the Channel, it was considered preferable to run the trial in waters not frequented by shipping, and, therefore, no attempt could be made to ascertain the speed. This was not necessary, as the two preceding ships—the *Minotaur* and the *Shannon*—easily exceeded the speed aimed at—23 knots—with the designed power, and the *Defence* exceeded this designed power by 570 I.H.P. The rates of coal and water consumption per unit of power were satisfactorily low. The vessel also ran the prescribed trials at one-fifth and four-fifths power to determine the radius of action. On the latter of these 30 hours' trials, the power averaged 19,500 I.H.P. with the engines running at 115 revolutions, and the speed was 20.9 knots—a successful result.—"Engineering."

ITALIAN.

Otaria.—We illustrate the Italian submersible boat *Otaria*, built by the Fiat S. Georgio Company, of Spezia. Her surface displacement when fully loaded is 175 tons, and her displacement submerged is 215 tons. Her surface speed is 14 knots, and her speed when submerged 7 knots. The *Otaria* belongs to the *Glauco, Squalo, Narvalo* and *Tricheco* class of boats; her length is 30 meters (98 feet 6 inches), and her beam 4



THE ITALIAN SUBMERSIBLE BOAT "OTARIA."

meters (13 feet); she is 14 feet 6 inches deep and is provided with two torpedo-launching tubes. She has a radius of action of 500 miles at 10 knots. These boats were designed by Engineer Naval Constructor C. Laurenti; the *Glauco* was completed in 1904, and the *Squalo* and *Narvalo* in 1906. The *Tricheco* and *Otaria,* of the same type, were completed in 1907-8. They gave evidence of their perfect seaworthiness in various trial runs between different Italian seaports and under water through narrow straits; they also took part in various maneuvers with the fleet, when several of their attacks upon battleships at anchor, guarded by torpedo boats, proved successful. These five submersible boats are an improvement upon the *Delfino,* the first boat of the type built and experimented upon by the Italian naval authorities. The *Delfino* having been completed in 1896, the course of experiments with this first boat, which led to the improved *Glauco* class, was therefore spread over a period of ten years. A sixth submarine, the *Foca,* was commenced in September last; this is to have a length of 42 meters (137 feet 9 inches), a displacement little above those of the *Glauco* class, as far as can be gathered at this stage, and a speed, when submerged, of 9 knots, and a 15 knots surface speed.

The *Otaria* and *Tricheco* are both fitted with Thornycroft internal-combustion engines, built to use normally paraffin as fuel. Each boat has two eight-cylinder sets of engines; each set drives a propeller and is capable of developing 350 brake horsepower, giving a total of 700 horsepower for each submersible. The eight-cylinder type of engine is obtained by coupling together two four-cylinder sets, each of which is complete in itself and can run separately from the other; the coupling being, however, rigid, the adjoining four-cylinder set runs idle in such a case. The engines are started by compressed air from the compressed-air receivers on board, a separate set of mechanically-driven starting valves, which open on the firing stroke, controlling its admission to the cylinders. These starting valves are below the cam shaft, and are operated by rock levers and trip rods in the same way, practically,

as the main valves; they are thrown out of gear by gearing and adjustable tappets directly the engines commence running with liquid fuel. The engines can revolve in both directions; reversal rotation of the crank shaft is obtained by operating a system of bevel-wheel gearing fitted on the cam shaft.—"Engineering."

SIAMESE.

A Siamese Revenue Cruiser.—The revenue cruiser *Suriya Monthon,* recently completed by Messrs. John I. Thornycroft & Co., Limited, Southampton, is of a type that is likely to become very useful where smuggling is still rife, and armed resistance is the rule in any encounters between Government officers and those engaged in defrauding the revenues. She is the second of her type built by Messrs. Thornycroft, the first being the *Amapa* for the Brazilian Government.

The particular duties of the *Suriya Monthon* will be the suppression of the existing practice of opium and firearms smuggling, which is carried on to a very great extent in Siam. In addition to this, however, she will prove a very handy and fast dispatch boat, and her seaworthiness is vouched for by the fact that the sister vessel, *Amapa,* crossed the Atlantic to Buenos Aires under her own power, and without any discomfort to the crew.

The vessel, which is illustrated, is 137 feet long over all, 135 feet on water line, and 130 feet between perpendiculars, by 18 feet beam, 9 feet 9 inches depth, molded, with a draught of 6 feet, and carries on her forecastle a 6-pounder Hotchkiss quick-firing gun.

The hull is of Siemens-Martin bullet-proof steel, and has fourteen water-tight bulkheads, one only of which is fitted with a water-tight door, the others being intact. The forward and aft decks are also water-tight. These precautions against foundering are rendered very necessary by the numerous uncharted coral reefs abounding in the seas in which she will cruise.

The machinery comprises two sets of three-cylinder surface-

condensing engines, with cylinders 9 inches, 13 inches and 20½ inches in diameter, respectively, by 11-inch stroke, and a Thornycroft water-tube boiler of 210 pounds working pressure,

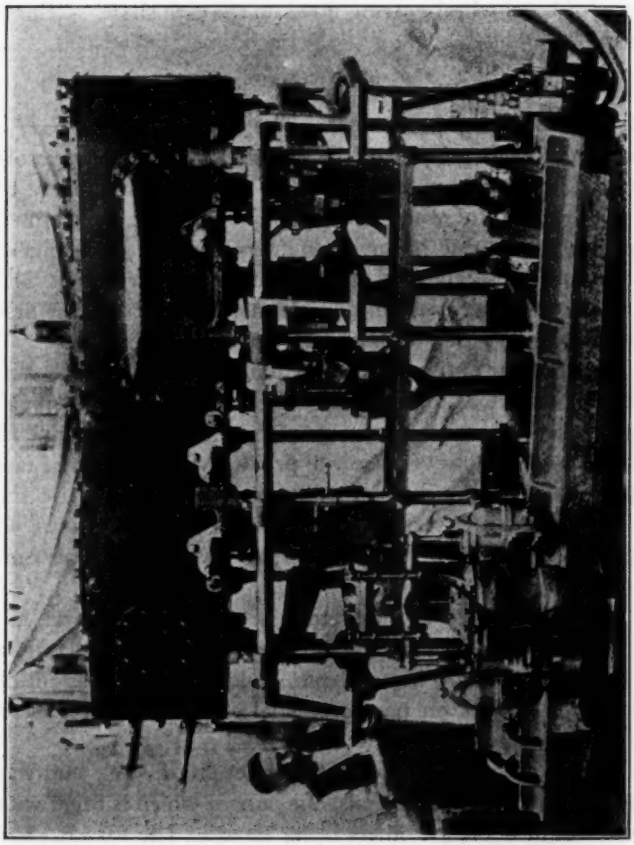
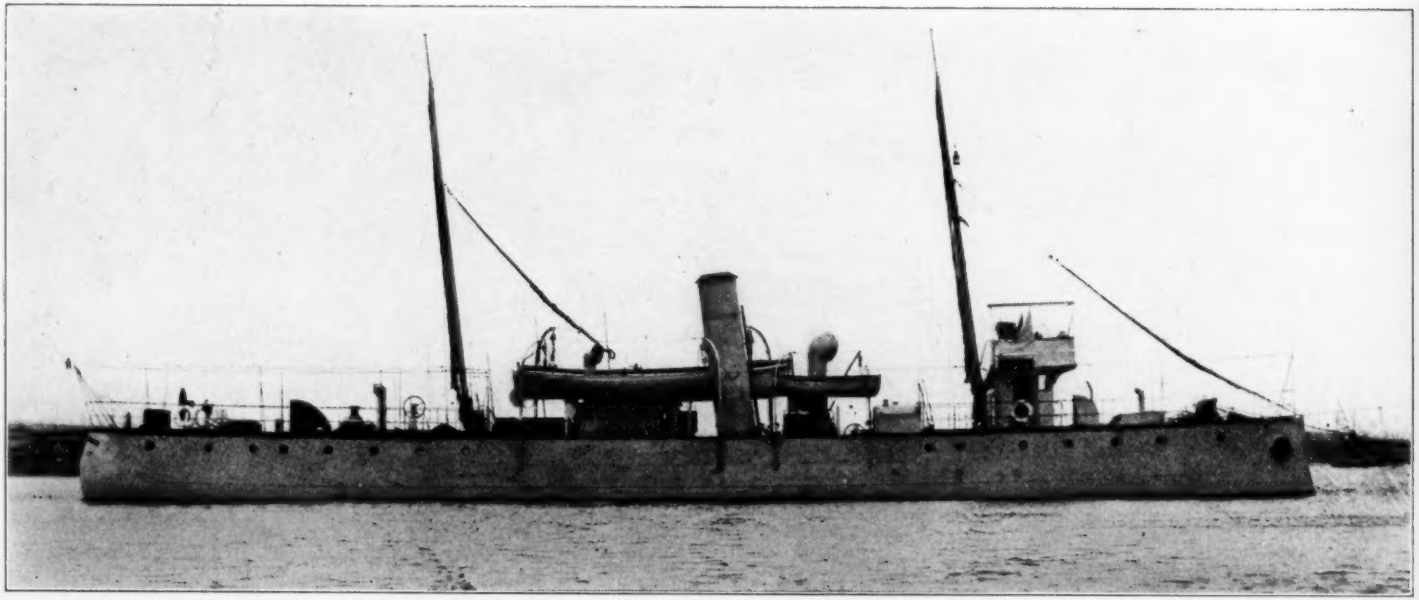


Fig. 12.

working under forced draft. The speed is 14½ knots, with a load of 40 tons, and 700 indicated horsepower. Two condensers, having separate circulating pumps, a Caird & Rayner evaporator capable of supplying 2½ tons of fresh water per



THE SIAMESE REVENUE CRUISER "SURIYA MONTHON."

24 hours, a drinking-water distiller and three steam pumps for feed, bilge and fire purposes, respectively, are provided.

The quarters are roomy and exceptionally well ventilated throughout by electric fans, those for the officers being under the raised quarter-deck aft (Fig. 5), and consisting of dining saloon, cabins for captain and six officers, with bath, pantry, lavatory, etc. The warrant officers' quarters and the crews' space are under the forecastle.

Fig. 13.—Motor Tender for Siamese Revenue Cutter.

Cold-storage accommodation is provided. The vessel is electrically lighted throughout all compartments, and a search-light projector of 10,000 candlepower is placed on the bridge.

Steering is controlled from the bridge by a steam engine, transmission being by shafting and bevel gear. A hand-steering wheel is also supplied. Another auxiliary is the steam windlass, fitted forward.

In addition to the ordinary ship's lifeboat and dingey, a motor tender will be carried. This is a standard-type Thornycroft launch, 30 feet long, built of teak throughout, and provided with the necessary cork belting, air tanks, etc., to pass the Board of Trade requirements for a lifeboat. The motor

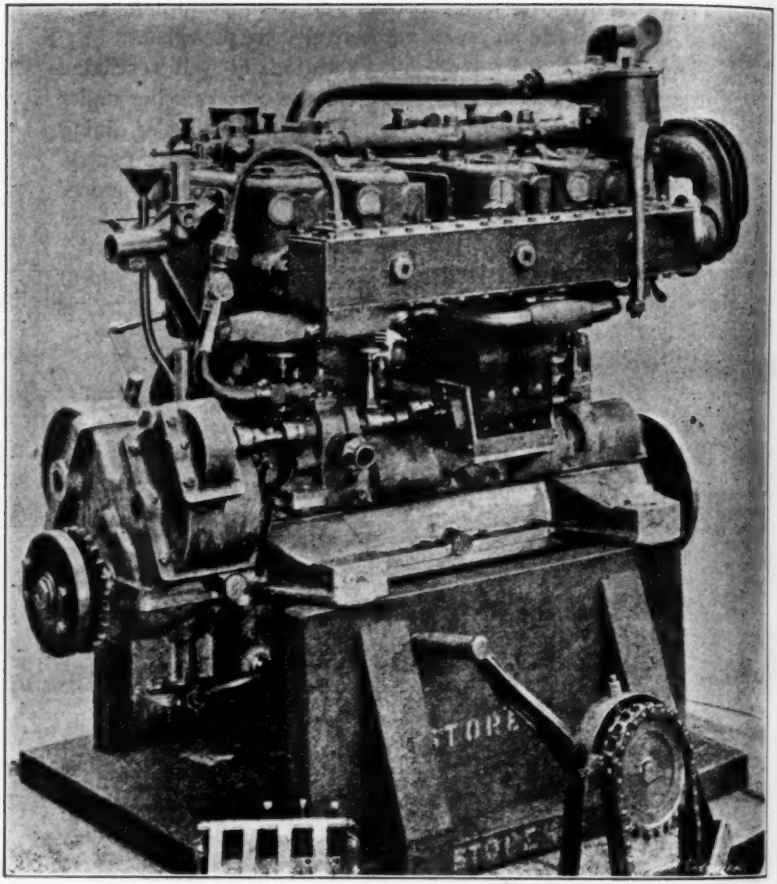
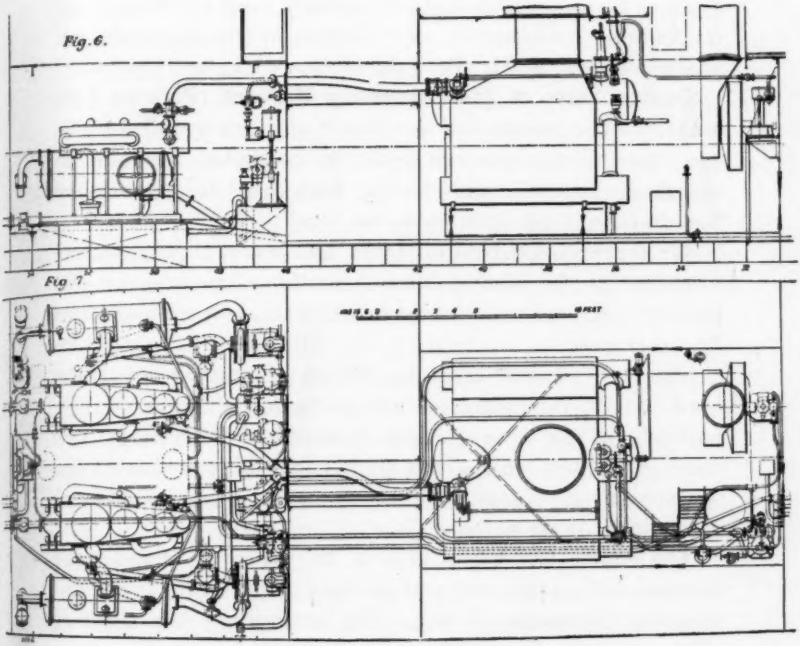
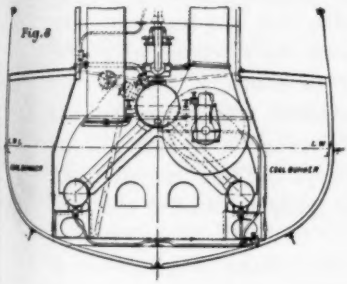


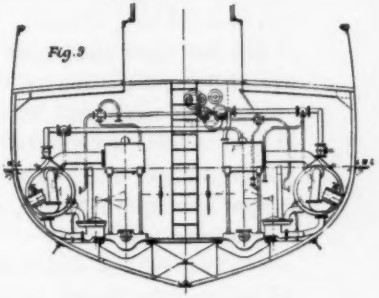
Fig. 14.

is the popular Thornycroft four-cylinder 4¼-inch by 5-inch type, developing from 23 to 26-brake horsepower, using paraffin as fuel. The speed of the launch is 12 miles per hour.

The contract speed for the cruiser of 14½ knots was easily exceeded by more than ¼ knot on the official trials, in the presence of Sir William H. White, K. C. B., who superin-







tended the construction on behalf of the Siamese Government.

A very pleasant trip round the Isle of Wight was made on the *Suriya Monthon* just prior to the vessel leaving for Siam, where she proceeds under her own power via the Suez Canal. The guests entertained included the Chargé d'Affaires for the

Siamese Government and His Excellency Lord Li Ching-fong, the Chinese Ambassador. Sir William White, being abroad, was represented by Mr. W. J. Harding.—"Engineering."

Service Tests of the Steamship Harvard (Parsons Turbine).*—The attention of members is particularly called to the fact that this test was run under the conditions obtaining in actual service, no attempt having been made to approximate the ideal conditions existing on the usual trial-trip runs.

We are much indebted to Mr. R. McGregor, General Superintendent of the Metropolitan Steamship Company, for the personal interest he manifested in the test and for the assistance he freely gave.

Observations were taken by Messrs. Young, Fisher, Hubbard and Davis, students of the Mechanical Engineering Department of the Massachusetts Institute of Technology, for thesis work; but the test was made under the direction of the Department of Naval Architecture, and under the personal supervision of the authors.

The engine test began at 9 P. M., when the engine had reached full power, and was stopped at 3 A. M., as we approached Nantucket Shoals. The last reading was taken at 2.55, when the first half-speed bell sounded, and the curves exterpolated to 3 o'clock. The boiler test was begun at 7.10 P. M., and continued until 7 o'clock the next morning, the curves being exterpolated to make 12 hours.

Pressures were read, as far as possible, on the engine-room gauges, which were tested for the occasion by the Crosby Steam Gauge and Valve Company. Where engine-room gauges were not available, Institute gauges, tested at our own laboratories, were used.

The horsepower was determined by means of the Denny & Johnson torsion meter, belonging to the Department of Naval Architecture at the Institute of Technology. The inductors were so set as to give a clear length of shaft between inductors of 63.06 feet on center shaft, 47.52 feet starboard and 49.21

*By Professor C. H. PEABODY, Member of Council, W. S. LELAND, Esq., and H. A. EVERETT, Esq., Members.

feet port, which gave readings of approximately 95, 75 and 70, respectively, at full power.

Inductors were set on all three shafts, but during the test the port recorder failed to work at the end of two hours, due to a rupture of the connections. From the few readings thus obtained, and from readings taken on a preliminary run, when it did work satisfactorily, it appears that the torque readings on this shaft were 93 per cent. of those on the starboard, and in computing the horsepower this figure has been taken. This, of course, throws some little uncertainty into the calculation, but there is every reason to believe that the assumption is very nearly correct. It would take practically 3 per cent. error on this shaft to affect the total horsepower by so much as 1 per cent. The torsion meter can be read only to single units, so that this of itself means an uncertainty in the last digit, which corresponds to an accuracy of about 1¼ per cent. When, however, the readings are plotted at 10-minute intervals, as is here done, and the results faired, the probable error is likely to be much less.

In computing the horsepower 1.506 based on a torsional modulus of elasticity of 11,600,000 was used for the constant K in the formula horsepower $= \frac{Kd^4rR}{CL}$, in which $d =$ the diameter of the shaft in inches (8 inches), $r =$ torsion meter reading, $R =$ revolutions per minute, $C =$ inductor constant (12.5), $L =$ length of shaft in feet between inductors.

The shaft was not twisted to determine the exact constant, but since 11,600,000 is the mean of a large number of tests it cannot be far from right. We find 11,000,000 and 12,000,000 to be practically the minimum and maximum values, showing a variation of about 3 per cent. only in extreme cases. That the actual modulus of the *Harvard's* shaft should vary from the mean value by more than 1½ per cent. is extremely improbable. All in all, taking into account the uncertainty of the port shaft, there is every reason to believe that the horsepower is subject to an error less than that of the ordinary steam-engine indicator.

The water consumption was measured by a 6-inch Hersey hot-water meter loaned by the Hersey Manufacturing Company, of South Boston. It was installed in the suction line between the hot well and the feed pump, and gave exceedingly satisfactory results. This meter was previously calibrated by the Hersey company, and indicated an under-run of 1 per cent. under the conditions of the test. The curve of meter readings was plotted without this correction, so that 1 per cent. should be added to any ordinate of that curve to get the correct reading.

Steam for all the auxiliaries excepting the blowers came through the starboard pipe only, in which a thin plate having a 2½-inch orifice was inserted. The valve on the port line was tightly closed and the by-pass around the reducing valve on the auxiliary line opened so that all the reduction in pressure was due to the orifice. The reduced pressures were read on the auxiliary steam gauge on the engine-room gauge board and the flow of steam computed from coefficients determined by experiments made at our engineering laboratories. An independent orifice was necessary for the blower engines as this steam did not come from the auxiliary line. The curve of auxiliary-steam consumption shows the total from these two orifices.

The probable error in determining the auxiliary steam is small. The gauge pressures were read to the nearest pound every 10 minutes and the average must be very nearly right. An error of one pound in this average would mean about 2 per cent. error in the total auxiliary steam, but even if the error here were four times as great it would be of small moment, for the auxiliary steam is only about 13½ per cent. of the total.

The coal was determined by counting the buckets dumped on the floor. Every hour the amount of unburned fuel on the floor was estimated, the corresonding points plotted, and the coal-consumption curve drawn through them. The average net weight of coal was 506 pounds per bucket. Such a method as this for coal determination is open to question, but is perhaps the best that can be adopted on a short sea run. Even

had the coal been weighed, the different condition of the fires at start and finish might have been considerable in so short a run. There is every reason to believe that any determination for so short a run would be somewhat too small. Our figures seem to show 80 tons for 12 hours equal to 100 tons for 15 hours, the running time from dock to dock, and this figure checks remarkably well with the amount of coal actually placed on board, an average being taken over a large number of trips.

The quality of steam was determined by the throttling calorimeter, the sample being taken from a tee on the top of the steam main, inserted for this purpose where the pipe was tapped for the gauge connection.

For the sake of simplicity only those observations appear in the plot which vary from the curve by an amount greater than the possible accuracy of observation. The close similarity of the curves and the small number of points through which the curves do not pass, is a strong check on the accuracy of the observations.

The following tables give the summary of the results and the principal dimensions of the vessel:

DIMENSIONS.

Length between perpendiculars, feet and inches	386-06
Breadth of hull, molded, feet and inches	50-06
over guards, feet	63
Depth, molded, feet	22
Draught, normal, feet	16
Draught at trial (mean New York to Boston), feet and inches	16-02

RESULTS OF BOILER TEST.

Date of test	25th June, 1908
Duration of test, hours	12
Boiler pressure, average, gauge, pounds	137.8
Quality of steam	95.9
Barometer, inches	29.97
Temperature of feed water, degrees	203.5
Draft of blower (Houdon), inches	1.71
Number of boilers (single-ended Scotch)	12
Total grate area, square feet	756
heating surface, square feet	29,520
Ratio heating to grate area	38.6

Total coal fired in 12 hours, pounds	179,112
water fed in 12 hours, pounds	2,041,710
Equivalent evaporation from and at 212 degrees, per lb. of coal	11.12
Coal per square foot grate area	19.6

RESULTS OF ENGINE TEST.

Type of engine	Parson's turbine
Duration of test, hours	6
High-pressure gauge, pounds	124.4
Low-pressure gauge (average starboard and port), pounds	21.3
Vacuum (average starboard and port), pounds	27.42
Temperature of injection water, degrees Fahrenheit	63.5
discharge water, degrees Fahrenheit	107
hot-well, degrees Fahrenheit	110.8
Total water per hour during test	176,010
Maximum revolutions, port	468
center	472
starboard	472
Minimum revolutions, port	433
center	444
starboard	441
Average revolutions (6 hours)	455
Maximum shaft horsepower	11,076
Minimum shaft horsepower	9,525
Average shaft horsepower (6 hours)	10,405
Steam for auxiliaries per hour, pounds	22,380
(4 per cent. primings) per shaft horsepower per hour, all purposes, pounds	16.9
(4 per cent. primings) per shaft horsepower per hour, turbines only, pounds	14.76
B. T. U. per shaft horsepower per minute	265.9
Coal per shaft horsepower (average of 6 hours), pounds	1.5

MERCHANT SHIPS.

New P. and O. Liner Morea.—The new Peninsular and Oriental twin-screw steamship *Morea* was tried for speed on the 4th inst., and again on the 5th, when a large party of friends of the builders and owners were on board. The keel of this new liner was laid down by Barclay, Curle & Co., Whiteinch, on November 5th, 1907. The time thus taken to build and engine the vessel and practically complete her for service has been exactly twelve months, from keel laying to official trial trip. She was launched on August 15th, so that the work of building in the yard only occupied nine months, and fitting her out for service three months.

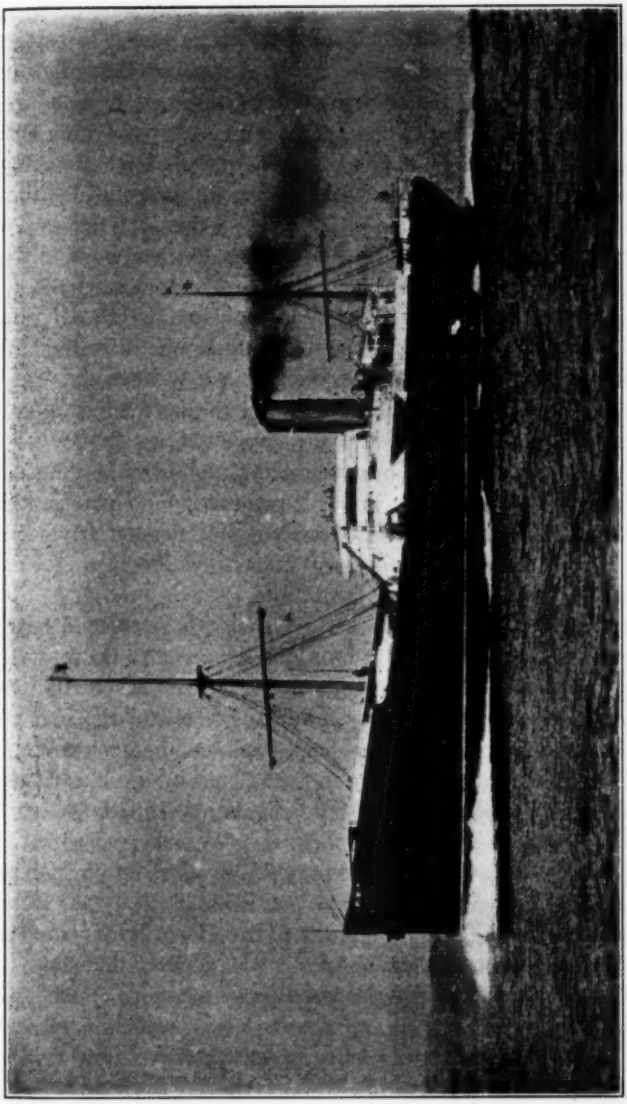
The principal dimensions of the *Morea* are: Length, 580 feet; breadth, 61 feet 6 inches; depth, 39 feet; and tonnage, 11,500 tons gross. The hull is built of Siemens-Martin mild steel, and is divided into numerous water-tight compartments by transverse bulkheads, and with a complete inner bottom fitted all fore and aft. There are four complete decks, viz: orlop, lower, main and upper—sheathed with teak and yellow pine. Above the spar deck is a long forecastle, a midship hurricane deck and poop deck aft. Above the midship-promenade deck is the boat deck, at the fore end of which are placed the captain's and officers' rooms, surrounded by the wheel house and two flying bridges.

The steam-steering gear is in a steel house immediately over the rudderhead, actuated by Brown's telemotor gear from the bridge and aft, and hand-steering gear is fitted for use in the event of a breakdown in the steam gear. The appliances for mooring the ship include a large Harfield steam windlass, two steam capstans on the forecastlehead and two steam warping capstans aft. Telephonic communication is provided between the windlass and the navigating bridge, and between other parts

where rapid communication is essential. In a large chartroom and wheel house on the navigating bridge, besides the steering wheels and Kelvin compasses and other navigating appliances, there are docking and steering telegraphs, speaking tubes and loud-speaking telephones to the engine room, forecastlehead and the aft end of the vessel. Throughout the vessel there is in every way full provision of appliances fitted for navigating and working the ship.

The machinery for propelling the *Morea,* which has been constructed by the builders, consists of two sets of four-crank quadruple-expansion balanced engines. There are eight boilers working at a pressure of 215 pounds per square inch, four of which are double-ended and four single-ended. Collectively there are 36 furnaces, which work under Howden's forced-draft system, and have four large fans electrically driven. The outfit of auxiliary machinery in the engine room is unusually comprehensive, and includes fourteen separate steam pumps, an ash expeller, a feed-water evaporator and a distilling plant. Evaporating and filtering plant is fitted both in the engine room and for the refrigerating machinery. A special feature is the ash expeller, whereby the ashes are put out through the ship's bottom. On the occasion of the trials, on November 4th, the *Morea* attained a speed of over 18 knots over the measured-mile course, and ran for a lengthened period at a uniform rate of revolution.—"The Engineer."

Combined Reciprocating and Turbine Machinery.—The steamer *Otaki,* built by Messrs. William Denny & Bros., Dumbarton, for the New Zealand Shipping Company, Ltd., has just completed her trials on the Clyde. This, as our readers are aware, is the first merchant vessel fitted with the combination of reciprocating and turbine machinery, the only previous case being the destroyer *Velox.* In that case, for cruising purposes, reciprocating engines were fitted at the forward end of the turbines and were connected up when low speed was desired, but in the case of the *Otaki* the attempt has been made to obtain greater efficiency by adding a turbine with separate screw to the usual reciprocating-engine equipment. It



THE S. S. "OTAKI" ON HER TRIALS.

has been generally recognized that if the screws of a vessel are to be driven directly by turbines, for cargo vessels or vessels of moderate speed, such as the *Otaki,* it was commercially impracticable to have a complete outfit of turbines, and the arrangement in the *Otaki* has been designed to overcome this difficulty. The vessel is fitted with two sets of reciprocating engines, driving twin screws fitted in the ordinary fashion, but between these two engines is fitted a low-pressure turbine of very large size. The steam after having done its work in the reciprocating engines, instead of entering the condenser directly, is passed through the low-pressure turbine, which drives a center screw. The turbine revolves only in one direction, the turbine screw being used for propoulsion solely when the vessel is going ahead; change valves are fitted so that the steam may be either passed directly into the condenser, or to the low-pressure turbines, hence, in maneuvering, the vessel becomes an ordinary twin screw, the center screw taking no part in the driving of the vessel. The twin-screw engines are triple expansion of the ordinary design, having cylinders 24½-inch, 39-inch and 58-inch by 39-inch stroke.

An Interesting Comparison.—The *Otaki* is virtually a sister ship to the *Orari,* which was built and delivered in 1906 to the same company, and when Messrs. Denny were consulted about the building of another vessel, they suggested to the owners the desirability of making an experiment with the combined engine. The owners, with their characteristic go-aheadness, agreed to the experiment; the only stipulations they made were that the builders should give them a reasonable guarantee as to efficiency, and that the capacity of the vessel should not be reduced. The boiler installation was to be precisely the same as in the *Orari.* The only alteration, therefore, that was made by the builders was that the length was slightly increased in the *Otaki* to make up for the loss due to the three funnels as against two in the *Orari,* and the stern post was so arranged that the third screw could be fitted in an aperture. The dimensions of the *Otaki* are 464 feet 6 inches by 60 feet by 34 feet—4 feet 6 inches longer than the *Orari,* otherwise the same. The

trials took place on Saturday and were successful; both the reciprocating engines and the turbines ran with the greatest smoothness. On the completion of the trials it was found that the average mean speed of the *Otaki* was 15.02 knots, while the average speed of the *Orari* under similar conditions was 14.6 As the boiler installation is precisely the same, this gives an excellent idea as to the increased efficiency of the machinery. The builders express themselves as satisfied with the result, and anticipate that the improved efficiency shown on trial will be maintained during the sea work of the vessel. As this vessel's trade is between this country and New Zealand, a voyage of practically 13,000 miles each way, there will be an excellent opportunity for proving the advantages of this system. The owners' official trial has practically confirmed the above results, except that the speed, instead of being 15.02, was 15.09. The *Otaki* required only 12.3 pounds of water per I.H.P. for all purposes.—"Page's Weekly."

Combination of Marine Reciprocating and Turbine Machinery.—The first merchant steamer fitted with reciprocating engines and a low-pressure turbine working in series has completed her trials, and although the vessel is only of 15 knots' speed, the results show the highest efficiency alike in respect to steam consumption and propulsion, the gain in speed being half a knot, while the water consumption seems to have been about 12.3 pounds per horsepower per hour for all purposes. This latter figure, however, has been arrived at by assumption; and, although it is based on very accurate data, it must not be accepted as a completely-established result. Even allowing for a margin of error, it seems clear that the vessel, when she goes into service, will easily establish her superiority. Fortunately, in the same service—the British and New Zealand service of the New Zealand Shipping Company—her performances can be compared with a twin-screw steamer with piston engines, but otherwise as nearly alike in design as circumstances would permit. The vessel with ordinary reciprocating machinery—the *Orari*—was built in 1906 by Messrs. William Denny & Bros., Dumbarton, and later, when they were consulted regarding the

building of a sister ship, they advocated the adoption of the combination-turbine system. In this advocacy they were only repeating the enterprise displayed by them in the early adoption of the turbine; and it will ever remain an important item in its history that the Dumbarton firm were the first to fit it to a merchant ship. The New Zealand Shipping Company showed splendid courage in adopting the suggestion, satisfied, no doubt, that the experience of the builders warranted confidence in their recommendations. In the new steamer, which is named the *Otaki,* the low-pressure turbine drives the center shaft, the reciprocating engines operating the wing shafts. Owing to there being three tunnels instead of two, and in order to provide the same cargo storage, the ship had to be made 4 feet 6 inches longer than her sister ships, her length being 464 feet 6 inches, her beam 60 feet and the molded depth 34 feet. The proportions of cylinders and the arrangements for cut-off in the reciprocating engines of the *Otaki* were determined with due regard for the use of exhaust steam in the turbine. The cylinders are 24½ inches, 39 inches and 58 inches in diameter, with a stroke of 39 inches. The tests of the vessel have been completed, and on the official runs it was found that the speed was 15.09 knots, and on corresponding builders' trials 15.02 knots. These results compare with 14.6 knots in the *Orari.* It is not possible accurately to compare the power and speed, but by producing the progressive speed curves of the *Orari* and *Opawa* to a point corresponding with the 15-knot speed of the *Otaki,* the probable indicated horsepower for 15 knots was found with some degree of accuracy, as the form of the *Otaki* corresponds exactly with that of the other vessels. From this power it is computed that at 15 knots speed the steam consumption equalled 12.3 pounds per indicated horsepower per hour. But the work in service will give the most accurate and reliable data, and we shall look forward with interest to the final issue of this interesting application. It should be added that the Parsons Marine Steam Turbine Company have completed the equipment of a steam yacht, but in this case the designers were handicapped by the fact that the system is being applied on the

twin-screw principle, one shaft being driven by the reciprocating engine, and the other by the turbine using the exhaust steam. This fact, combined with the circumstance that it has not been possible so to arrange the proportion of cylinders and cut-off as to give the best result in combination, may render it impracticable to obtain the same measure of the efficiency of the system as is demonstrated by a comparison of the results of the *Orari* and *Otaki*. Messrs. Harland & Wolff are also fitting a combination system, corresponding generally to that fitted in Messrs. Denny's boat; but the Belfast ship is much larger, although not designed to attain high speed.—"Engineering."

OBITUARY.

NATHAN PRATT TOWNE.

WRITTEN BY CAPTAIN J. R. EDWARDS, U. S. NAVY.

For nearly fifty years the late Nathan Pratt Towne was identified with naval-engineering progress and development. Entering the Navy early in January, 1862, he was shortly afterwards ordered to the sloop-of-war *San Jacinto*, and while attached to that vessel his interest in marine-engineering matters was of such zealous nature as to attract the particular attention of his Chief Engineer and to mark him as a man of unusual attainments.

Previous to entering the Naval Service he had acquired a good classical education, as well as considerable mechanical training and experience. His early life was spent at Bath, Maine, and his boyhood associations and environments were such that he became exceedingly interested and familiar with the romance and habit of the sea. The sea captains of that day were masters in concisely, strongly and clearly giving orders, and by association with these men he acquired a directness of speech, as well as mastery in presenting statements, that ever made him a forceful man amongst his confreres.

He possessed intense application of purpose, remarkable mechanical judgment, and was ever exceedingly observant of the trend of naval-engineering progress and advancement. Particularly was he a student of men; and as he had been associated in professional work and research with such engineering leaders as John Ericsson, Charles H. Haswell, Benjamin F. Isherwood, Charles H. Loring and George W. Melville, it was not surprising that he was regarded, even up to the day of his death, as one of the ablest and most progressive of the country's naval-engineering authorities.

Thirty years after entering the Navy he was granted leave of absence to accept a temporary appointment with the Cramp Shipbuilding Company as its supervising and designing marine engineer. When this offer was made he was an assistant to Rear Admiral Melville, at the Navy Department, his special duty being in charge of the work of preparing the designs of the machinery of the new Navy. The machinery designs of the historic *Brooklyn* and *Oregon,* as well as the triple-screw cruisers *Minneapolis* and *Columbia,* were prepared while he was in charge of the designing and draughting room. His love for the Service was keen, and it was with great reluctance that he severed this association to accept a permanent appointment with the Cramp corporation. He rendered valuable service to the firm, and neither the name nor the fame of the Cramp Company was ever impaired by the character of the machinery designs turned out under his supervision and direction. As evidence of his progressive engineering ability the latest distinct innovation in naval propelling machinery—the installation of the Zoelly marine turbine—is now being effected in two of the torpedo-boat destroyers that are in process of construction for the Government.

The diversity of his engineering talent may be attested by the fact that while in the employ of the Cramp Company his duties not only comprised the designing of all boilers, steam pumps, ash-hoisting, refrigerating and propelling machinery, but likewise all mechanical-design work in connection with the bilge and ballast drainage, boat cranes, ammunition hoists and turret-turning appliances.

His designing ability and engineering knowledge was of a comprehensive and general character rather than of a special technical or distinct nature. The result of his study, resourcefulness and experience was therefore exemplified in special features of the machinery design of warships of the Japanese, Russian, Turkish and American navies, the Cramp Company having built naval vessels for all these governments.

While advancing age and increasing work did not appear to diminish either his mental or professional attainments, it

was particularly noticeable that, during the closing period of his life, his judgment of the work of others was not of the severity of previous years. There was a striking change in his method and manner of meeting and overcoming opposition, and the pent-up affection for the work of the old Engineer Corps of the Navy manifested itself in frequent ways. The traditions, recollections and events connected with the ships he had cruised in, and the retrospection of his naval career, gave him ineffable satisfaction and comfort, and it was his last wish that there should be placed with his ashes the medal bestowed upon him for service in the Civil War.

He will be affectionately remembered by the older officers of the Navy and amongst his contemporaries in civil life as one of the most interesting raconteurs of the service. His linguistic talent, extensive reading of the best literature, keen power of observation and remarkable ability to coin stories applicable to existing circumstances, not only made him a forceful antagonist in discussion, but distinguished him alike as either a delightful host or entertaining guest. During the period that General Grant cruised on the U. S. S. *Richmond* in Asiatic waters, it is said that he often sent for Mr. Towne to have him tell in his inimitable and striking manner of the folklore of the sea, and of the spirit, customs and traditions of the Navy of the previous generation. It is a matter of sincere regret that the recollections of such a man as regards the steerage and ward-room life of the old auxiliary steam Navy were not collated and published, since these stories and tales would have told of actual experiences that now almost appear myths and traditions. The spirit of these stories would have also impressed the strenuous junior officers of the present decade with the loving, lovable, courageous and efficient nature of their predecessors of the days when sail was the principal and steam the auxiliary power of the warships of nations.

By reason of his exceptional professional ability his work was ever in evidence in engineering circles, and yet he was always reluctant to seek either the favor or commendation of others. His election as President of the American Society of

Naval Engineers bears testimony as to the esteem in which he was held by the officers of the Navy.

His career, in many respects, typified the storm rather than the calm of the sea. His life work, however, was of benefit to the nation, since, as regards design, some of the distinct engineering triumphs of the American Navy can, in good part, be ascribed to his inventive engineering talent. In the quiet and peace of Arlington he sleeps, his death having occurred April 23, 1909.

ALBERT FIRMAN DIXON.

WRITTEN BY COMMANDER B. C. BRYAN, U. S. N.

The death of Captain Albert Firman Dixon, U. S. Navy, which occurred in New York City on March 10, 1909, takes from the Service a valuable and efficient officer and from those who knew him a beloved and valued friend.

Captain Dixon was born in the Portsmouth Navy Yard, Kittery, Maine, December 22, 1849. He was educated at the Boston public schools, and entered the Navy as a Second Assistant Engineer on October 29, 1870, and at the time of his death was the senior member of the old Engineer Corps on the active list of the Navy.

During his service of nearly thirty-eight years he was at sea twenty-one years, and served on every station and on many vessels, beginning with the *California* in 1871, then successively on the *Ajax, Tuscarora, Wachussetts, Boston, Vesuvius, Machias, Detroit, Chicago, Brooklyn* and *Oregon.* On this latter vessel he served as fleet engineer of the Asiatic Station and took part in the campaign against the Boxer uprising in China.

On shore he held many posts of responsibility, being a member of the Board to inspect and select merchant vessels during the Spanish war, as Chief Engineer of the Mare Island Navy Yard, 1901 to 1904, as Assistant Chief of the Bureau of Steam Engineering, 1904 to 1908, and at the time of his death he was General Inspector of Machinery for the Navy and member of

all Boards on changes in machinery of vessels building on the Atlantic coast.

Captain Dixon was zealous in his duties and master of every detail of his profession. He was always courteous, kindly and generous to everyone, and possessed of the rare gift of interest and sympathy in the affairs of young people, to whom he was especially endeared.

He was a member of many clubs in various parts of the world and was always prominent and active in his membership. Among them were the Army and Navy Clubs of Washington, of New York and of Manila, Bohemian Club of San Francisco, and New York and Atlantic Yacht Clubs. He was also a member of the Military Order of the Dragon and Military Order of the Carabao.

He was married in 1876 to Miss Stella May Woods, daughter of John H. Woods, a merchant of Honolulu, and is survived by his widow, one son and one grandson.

BOOKS REVIEWED.

"MARINE BOILERS AND ACCESSORIES,"* by L. JAUCH and A. MASMEJEAN, Engineer Officers, Professors at the Toulon Engineering School, and old scholars of the National School of Arts and Science. (In French.)

This volume of 514 (6½ inches by 10 inches) pages, well illustrated, together with an 8-inch by 11-inch book of folded plates, treats the subject of marine boilers and fitting in a most thorough and interesting manner.

The work opens with brief notes on the strength of materials. Then follows some notes on thermo-dynamics, which cover the subject in a concise, though thorough, manner.

The subject proper commences with Chapter I, which immediately follows the above notes. This chapter is introductory in nature, touching the general classifications of boilers and terms used. Chapters II and III are devoted to the details of boiler construction, aided by interesting cuts and figures. Chapter IV covers the subject of combustion and draft. The portion on forced draft appears to be very thorough. Mounting and internal fittings are dealt with in Chapter V. The notes on the Klinger reflex water gauge command attention, covering, as they do, the fundamental principles of this type gauge glass, a matter generally omitted in works of this kind, it being assumed that everybody understands. Chapters VI and VII treat briefly the wear and tear and preservation of boilers, and water circulation in boilers, respectively. The principal types of marine boilers are described and discussed at length in Chapter VIII, together with their adaptability to the different services; and Chapter X supplements the subject with a brief description of several types of boilers for small vessels and launches. Both chapters are well sup-

* Reviewed by Henderson B. Gregory, Associate.

plied with illustrations. Chapter XI covers the important subject of feeding boilers. Feed pumps, feed-water heaters, filters, grease extractors, etc., are described at length and well illustrated by cuts and plates. Chapter XII is devoted to distilling apparatus, and is in keeping in thoroughness with the rest of the book. The economy of boilers, their care and management, fuel and gas analyses, are briefly treated in Chapter XIII; also a short description of ash ejectors, etc. Chapter XIV handles the subject of oil fuel in a concise and satisfactory manner, very practically illustrated. Steam pipes and fittings, well illustrated, are covered in great detail in Chapter XV. The plates showing the steam-piping arrangement on several French warships are extremely interesting and instructive, and also indicate a desire on the part of the authors to make this chapter of practical value. The work closes with Chapter XVI, which deals briefly with boiler tests.

On the whole, this work is well written and covers the ground in a very instructive and practical way. It is not merely descriptive, but also technical, containing the essential formulæ for design.

The book of plates deserves special mention, the numerous cuts being well selected and giving much detail.

Published: Toulon, J. ALTE, editeur, Quai Constadt.

THE MARINE PROPELLER AND ITS ACTION UPON THE WATER.* By PROF. OSWALD FLAMM. Size, 7¾ by 11⅛ inches. Pages, 23. Plates, 31. Munchen and Berlin, 1909. R. OLDENBOURG. Price, 12 marks.

The present work is the first preliminary result of numerous experiments made with model propellers in a basin. The work is not as yet a final one, but still it represents material which will be of interest to professional colleagues and surely might be permitted to bring a correct explanation to the many views hitherto held. The main object of its publication was to place freely at the disposal of professional men the larger portion of the material accumulated in photographs and the data relating

* Reviewed by Wm. Wachsmann, Associate.

thereto, so as to also arouse their interest in drawing conclusions from the photographs, and thereby strive to advance in the design of propellers.

In the series of investigations with the propeller models the progressive speed is made a function of the revolutions and pitch. The motion of the water, formation of cavities, and the phenomena upon going astern, etc., appearing are fixed by photographs up to 3,600 revolutions per minute, and are rendered in 192 stereo-views. The results, with simultaneous measurements of revolutions, progressive speed and blade thrust, give, in connection with the photographic views, an essential clearing up of the mode of action of a propeller working free in water.

These interesting as well as important investigations are entitled to deserved attention and will no doubt be welcomed in all circles interested in propeller design, the more so, since the author is regarded as an authority on this subject.

THEORY OF THE SCREW PROPELLER.—By inadvertence the source of the article on "Theory of the Screw Propeller," by von J. W. Haeussler, appearing in the August, 1908, number of the JOURNAL, was not mentioned. This valuable article was translated from "Die Turbine."

ASSOCIATION NOTES.

By direction of the Council, notice of conditions of award of prize essay is given.

A prize of fifty dollars and life membership in the Society will be awarded for the best original article submitted by a Member or Associate and published in the JOURNAL during the calendar year. This prize will be in addition to the regular rate paid for contributions. The prize essay will be decided upon by a vote of the Members of the Society.

SOCIETY BANQUET.

The Secretary-Treasurer has to announce that the banquet of the Society held at Raucher's, Washington, D. C., on May 7th, was a most successful event and one thoroughly enjoyed by all who attended.

Rear Admiral J. K. Barton, President of the Society, introduced as toastmaster Commander W. Strother Smith, who discharged the duties of that position in a most admirable manner.

The toasts were as follows:

"The President."—Responded to by Senator M. E. Clapp, member of the Naval Committee.

"The Navy."—Responded to by Rear Admiral C. S. Sperry, U. S. N.

"Naval Engineering."—Responded to by Rear Admiral Richard Wainwright, U. S. N.

"The Navy and the People."—Responded to by Representative W. E. Roberts, member of the Naval Committee.

Besides these, there were short speeches delivered by Representative A. F. Dawson, member of the Naval Committee; Assistant Secretary of the Navy Beekman Winthrop; Prof. F. R. Hutton, of Columbia University; Hon. L. A. Coolidge, late Assistant Secretary of the Treasury, and Mr. Robert Patchin, of the "New York Herald."

BANQUET. AMERICAN SOCIETY OF NAVAL ENGINEERS. MAY 7, 1909.

1 2 3 4 5 6 7 8 9 10 11 12 13 14

Mr. John Armour, of "Power and the Engineer," added much to the entertainment by giving some of his delightful recitations.

The success of this banquet has brought forth from many quarters the hope that the practice of giving a Society banquet each year may be established.

The following is a list of the guests and members who attended:

H. L. Aldrich; General J. B. Aleshire, U. S. Army; Darwin Almy, George Anthony, Edward R. Archer, J. Armour, Lewis Audenreid.

Captain F. H. Bailey, R. O. Bailey; Rear Admiral J. K. Barton, U. S. Navy; Lieutenant H. A. Baldridge, U. S. Navy; Commander F. W. Bartlett, U. S. Navy; Commander F. C. Bieg, U. S. Navy; Lieutenant R. L. Berry, U. S. Navy; Scott Bone, W. A. Bole, G. M. Bond, George K. Bradfield, J. A. Breckons, L. M. Brigham, George Brill; Commander B. C. Bryan, U. S. Navy; Lieutenant Commander H. V. Butler, U. S. Navy; Hon. J. C. Burrows.

Otto Carmichael; Captain E. H. Campbell, U. S. Navy; Lieutenant Commander L. H. Chandler, U. S. Navy; R. H. Chappell, Hon. M. E. Clapp, Walter E. Clark; Lieutenant Commander H. I. Cone, U. S. Navy; L. A. Coolidge, C. A. Cotterill.

Arthur P. Davis, O. K. Davis, Hon. A. F. Dawson, Charles Delanoy, John Derby; Lieutenant H. C. Dinger, U. S. Navy; T. Dunlap; Commander C. W. Dyson, U. S. Navy; Commander T. C. Fenton, U. S. Navy; W. D. Forbes, Koerting Fischer.

Lieutenant J. B. Gilmer, U. S. Navy; Hon. A. W. Gregg, H. B. Gregory; Commander R. S. Griffin, U. S. Navy.

Lieutenant Norman Hall, U. S. Revenue-Cutter Service; F. H. Halsey, General Harries, G. G. Hill, Hon. C. D. Hilles; Rear Admiral R. C. Hollyday, U. S. Navy; Lieutenant Commander U. T. Holmes, U. S. Navy; J. C. Hoyt, W. D. Hoxie; Captain John Hubbard, U. S. Navy; C. W. Hunt, Prof. F. R. Hutton.

Rear Admiral Richard Inch, U. S. Navy.

E. N. Janson, J. E. Jenks, Arthur Johnson.

L. H. Kenney; Lieutenant H. Kotzschmar, U. S. Revenue-Cutter Service.

Hon. Herman de Lagercrantz, Swedish Minister; John W. Lieb, John Lloyd, Charles Longstreth, Luther D. Lovekin, F. R. Lowe; Rear Admiral John Lowe, U. S. Navy; Lieutenant Commander J. M. Luby, U. S. Navy.

Engineer-in-Chief C. A. McAllister, U. S. Revenue-Cutter Service; Hon. C. McHarg; Rear Admiral T. C. McLean, U. S. Navy; Rear Admiral N. E. Mason, U. S. Navy; H. A. Magoun, Prof. Lionel Marks, E. D. Meir, A. B. L. Mesney, Fred J. Miller; Lieutenant Commander J. P. Morton, U. S. Navy; Richard Morton.

Commander H. P. Norton, U. S. Navy; L. B. Nutting.

J. C. O'Laughlin; Captain Hugo Osterhouse, U. S. Navy; C. B. Overbaugh.

Captain W. M. Parks, U. S. Navy; Robert Patchin, N. B. Payne, John Platt; Paymaster C. T. Peoples, U. S. Navy; Pitman Pulsifer.

A. H. Raynal; Lieutenant Commander M. E. Reed, U. S. Navy; Captain I. S. K. Reeves, U. S. Navy; Captain J. E. Reinburg, U. S. Revenue-Cutter Service; Hon. J. B. Reynolds, C. R. Richards, Calvin W. Rice, F. H. Rittenour, Hon. E. W. Roberts, F. E. Rodgers; Lieutenant C. S. Root, U. S. Revenue-Cutter Service; Captain W. G. Ross, U. S. Revenue-Cutter Service; T. F. Royland.

J. A. Seymour, Arthur Scrivener, W. E. Schoenborn; Commander W. S. Smith, U. S. Navy; James M. Smith; Pay Director J. N. Speel, U. S. Navy; Rear Admiral C. S. Sperry, U. S. Navy; F. Starck; Major Stanley, U. S. Army; J. A. Stewart; Lieutenant George Sweet, U. S. Navy.

Lieutenant Elisha Theall.

Hon. George Uhler.

Rear Admiral Richard Wainwright, U. S. Navy; Ernest Walker; Chief Engineer J. Q. Walton, U. S. Revenue-Cutter Service; Jesop Westesson; Commander W. W. White, U. S.

Navy; Hon. William H. Wiley, Hon. Beekman Winthrop, I. H. Woolson, Oresco Woolson; Captain Walter F. Worthington, U. S. Navy.

It is thought that this banquet will have a large influence in making the Society more widely known, enlarging the number of its members and friends, and assisting the Society in carrying out its aim in the promulgation and improvement of engineering knowledge throughout the Service.

The following comment appeared in the Army and Navy Register:

"A notable event in many respects, aside from the commensality of the occasion, was the banquet with which the members of the American Society of Naval Engineers celebrated the twenty-first anniversary of the organization of that body. The dinner occurred in Washington on Friday of last week, and was attended by representatives of Congress from both the House and Senate, by naval officers of distinguished service and by members of the American Society of Mechanical Engineers, lately in convention in Washington.

"The post-prandial addresses were out of the ordinary in the fact that the speakers had something to say and stopped when it was said. It is worth recording that the sentiment of the public expressions on that occasion was appreciative of naval engineering as a factor which contributes so directly and vitally to the success of naval operations. Such influential officers of the Service as Rear Admirals Sperry and Wainwright found it possible to give enthusiastic testimony of the efficiency of the engineering branch of the American ships of war, and especially the battleships of the circumnavigating cruise. The importance of naval engineering requires no exploitation, but it was well to have an opportunity to manifest service and congressional realization of what naval engineering has been, is and should be."

The accompanying photograph is reproduced through the courtesy of the "Army and Navy Register" and Photographers Harris & Ewing, of Washington, D. C.

H. C. DINGER,
Secretary-Treasurer.